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AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. I.—*The Origin and Significance of Spines: A Study in Evolution;* by CHARLES EMERSON BEECHER. (With Plate I.)

INTRODUCTION.

THE presence of spines in various plants and animals is, at times, most obvious to all mankind, and not unnaturally they have come to be regarded almost wholly in the light of defensive and offensive weapons. Their origin, too, is commonly explained as due to the influence of natural selection, resulting in the greater protection enjoyed by spiniferous organisms. But when, upon critical examination, it is seen that some animals are provided with spines which apparently interfere with the preservation of the individual, that other animals develop spines which cannot serve any purpose for protection or otherwise, and that spines themselves are often degenerate or suppressed organs, then it becomes evident that the spinose condition may have other interpretations than the single one of protection.

The object of this article is to make a few observations on spinosity, especially among invertebrate animals, and to endeavor to arrive at some general conclusions relating to the origin and significance of this condition. It is believed that the results have a broader application than is at first apparent, and underlie important laws and principles of organic evolution. In closely related species, the presence or absence of spines seems in itself a trivial character, indicating at best only specific differences, yet it will be shown that the spines are often the expression of important vital adjustments and conditions, and are not merely external features of the same value

as color and many other skin or superficial characters. As will be indicated later on, spines may also arise through the operations of a number of forces and conditions, and it may well be asked, therefore,—Do spines have any profound significance? It must be granted at the outset that apart from other characteristics, or when regarded as simple spiniform extensions of certain tissues or organs, they have no such value or meaning. How, then, should they be considered? The reply is evident: Their importance lies not in what they *are*, but in what they *represent*. They *are* simply prickles, thorns, spines, or horns; they *represent*, as will be shown, a stage of evolution, a degree of differentiation in the organism, a ratio of its adaptability to the environment, a result of selective forces, and a measure of vital power.

After studying numerous organisms, the writer is led to believe that in every case no single reason is sufficient to account for this spinose condition. The original cause may not be operative through the entire subsequent phylogeny, so that spines arising from external stimuli and then serving important defensive purposes may at a later period practically lose this function; or spines may become more and more developed simply by increasing diversity of growth forces, or through the multiplicity of effects. In this way, causes may follow, overlap, or even coincide with each other; but in interpreting special cases, the problems involved may be quite complicated and often obscure.

In reviewing the development of animal life from the earliest Cambrian to the present, one cannot avoid being impressed by the groups of spinose forms which appear here and there throughout geologic time, and give a special phase to contemporary faunas. Tracing these one by one through their geological development, it is noticed that each group began its history in small, smooth, or unornamented species. As these developed, the spinose forms became more abundant until after the culmination of the group is reached, when this type either became extinct or was continued in smaller and less specialized forms. In applying this principle to any order of plants or animals, several precautions are necessary. The estimate must be based approximately upon the general average of the totality of specific characters, whether a genus, family, order, or even a class is being considered. A short-lived family or genus, or the terminal members of specialized groups, therefore, cannot be taken as representing the developmental status of the larger divisions, because they culminated and disappeared independently of the culmination of the class to which they belong. On a small scale, however, each epitomizes the rise and decline of the larger group, and the principles of

correlation commonly applied in ontogeny and phylogeny can likewise be used in the study of spines and spiniferous species, with equally exact results, whenever the principal factors are understood.

Law of Variation.

Before undertaking any general or special examination of the life histories and interpretation of spinose organisms, it is desirable to consider briefly some of the biogenetic principles which are considered to bear directly on the problems here under discussion.

First among these is the law of variation or change, which is so generally recognized as to require but the briefest restatement.

The organic as well as the inorganic world is subject to all the forces of nature, internal and external, molecular and molar, and even a partial stability is gained only through a regulated adjustment. In organisms, this change is momentary and persistent, while in most inorganic substances, it is slow and intermittent. The results of this continual readjustment constitute modification, which may be progressive or regressive, continuous or discontinuous (in the sense of accelerated, uniform, or retarded). They are everywhere present and the causes always operative. Throughout life, the individual changes, and in addition varies from all other individuals. The family, also, changes with time, and likewise differs from other families. Variation is everywhere present. Moreover, it is generally accepted, and is so taken here, that, in its results, this variation is not haphazard, but is normally in accordance with certain demands or in harmony with certain surroundings. Whether an organism itself tends to vary in all directions, or is chiefly subject to modifications from external forces, does not alter the preceding statement.

Cope[11] has considered variation as either physico-chemical (molecular) or mechanical (molar). The influence of the first is known as physiogenesis and of the second as kinetogenesis. In the animal kingdom, the potency of kinetogenesis is greater as an efficient cause of evolution; while in the vegetable kingdom, physiogenesis is apparently of more importance.

The tendency of variation is always in the direction of the establishment of an equilibrium between the organism and its environment. However, the laws of the development of the earth preclude the possibility of a constant environment, and therefore a perfect, permanent, and uniform equilibrium between life and surroundings is unattainable.

The manner of variation is clearly defined as *progressive* and *regressive*. Progressive variation is one of the essential

factors of evolution, while regressive variation is towards dissolution. Since the main history of life is told through processes of the former, progressive variation is far greater in importance; while, in general, regressive variation can be applied only to late periods in the history of groups or forms now in their decadence, or to others which in past times have suffered decline and extinction.

The summary of the operation of the law of multiplication of effects, as given by Herbert Spencer[66], may well be stated here, as it emphasizes one of the principles through which spines have originated.

"It manifestly follows that a uniform force, falling on a uniform aggregate, must undergo dispersion; that falling on an aggregate made up of unlike parts, it must undergo dispersion from each part, as well as qualitative differentiations; that in proportion as the parts are unlike, these qualitative differentiations must be marked; that in proportion to the number of the parts, they must be numerous; that the secondary forces so produced must undergo further transformations while working equivalent transformations in the parts that change them; and similarly with the forces they generate. Thus the conclusions that a part-cause of evolution is the multiplication of effects, and that this increases in geometrical progression as the heterogeneity becomes greater, are not only to be established inductively, but are deducible from the deepest of all truths."

Modification, therefore, may properly include the results of the multiplication of effects. Furthermore, from a knowledge of the life history of the organic world, it is known that this change has been progressive, resulting in the evolution of the higher from the lower, of the complex from the simple, and of the definite from the indefinite.

It must now be asked,—Is the amount of variation without limit or is it restricted within bounds which can be determined? As far as can be seen, the limitations of the forms of species of animals and plants end only with the aggregate number of possibilities within the functional scope of the organism. Beyond, in either direction, is death, and a passage from the organic into the inorganic. The restrictions of variation are chiefly those of temperature, pressure, motion, light, space, time, and matter. Within certain limits, these clearly bound the horizon of known possible life. Further, the material constitution of the organic world is naturally subject to ordinary mechanical and chemical laws.

If, instead of the preceding, general, and therefore rather abstract statements of the limits of variation, the subject is

considered from the concrete, objective side, the limits between which are found all the variations actually presented by any character or set of characters, in the animal or the vegetable kingdoms, can at once be determined. The fact that the organic world can be divided into kingdoms, sub-kingdoms, classes, orders, etc., and definitions of the divisions given, in itself furnishes sufficient evidence that these have been the limits of organic change, at least under present terrestrial conditions. This does not imply that the phylogenies of groups of animals and plants do not converge and coalesce, and join larger and larger phyla in past ages, so that the gaps between unlike forms are gradually filled by complete series. It does, however, express the definite heterogeneity of the results of development.

For the sake of illustrating an extreme range of variation, it will be granted that the assemblage of characters by which a mammal is now recognized precludes mammalian variation into a cold-blooded, non-vertebrate, lungless animal. Likewise, the mammalian skeleton cannot be siliceous or chitinous. Externally, mammals may be smooth, hairy, scaly, or plated, but not feathered. There may be found numerous gradations from the smooth to the plated state, and a great range of variation in each type of epidermal structure. In vertebrate animals generally, the hair may vary in length, in fineness, in color and shape; it may form bristles, or spines, or feathers; and as a skin character, it is related to horn-sheaths, hoofs, nails, claws, scales, and teeth. These constitute the limits of modification in epidermal or exoskeletal growths. The types are few, but the variety in each is almost infinite. The variation may be seen in individuals, but becomes greater in species, and increases still more in larger groups. The gradations are numerous between the hair of a Beaver and the spines of a Porcupine; between the horns of the Giraffe, Rhinoceros, and Antelope; between the nails of Man and the claws of the Carnivora; and between the teeth of a Dog-fish and those of a Tiger.

Definition of Terms.

In the beginning, it is well to understand the meaning and extent of the terms included under the comprehensive word spine. In a general sense, *spine* is here used to cover any stiff, sharp-pointed process. A *prickle* is restricted in use to the small, sharp-pointed, conical projections which are purely cuticular; as in the Rose and Blackberry. A *thorn* is a sharp process on plants, usually representing a branch or stem. A *horn* is an excrescence on the head of certain animals, and is properly hollow. An *antler* is a solid bony process, usually

deciduous, and generally confined to the male; as in the Deer or Elk. A *spur* is a term applied to the claw-like process on the legs and wings of some birds, and on the hind legs of *Ornithorhynchus* and *Echidna.*

The word spine, therefore, is most comprehensive, and is here intended to include the modified hairs of the *Echidna* and Porcupine; the sharp, prickly scales of the Horned Toad (*Phrynosoma*); the pointed spiniform projections on the shells of Mollusca; the spinous prominences on the test of Crustacea and insects; the fin spines as well as those on the opercula and scales of fishes; the generally movable processes of Echinoderms; the projecting rays and processes of Radiolaria, etc., etc. The vertebral column and also the processes from the separate vertebræ are known as spines, but as these are distinctly internal structures, they will not be considered in this connection.

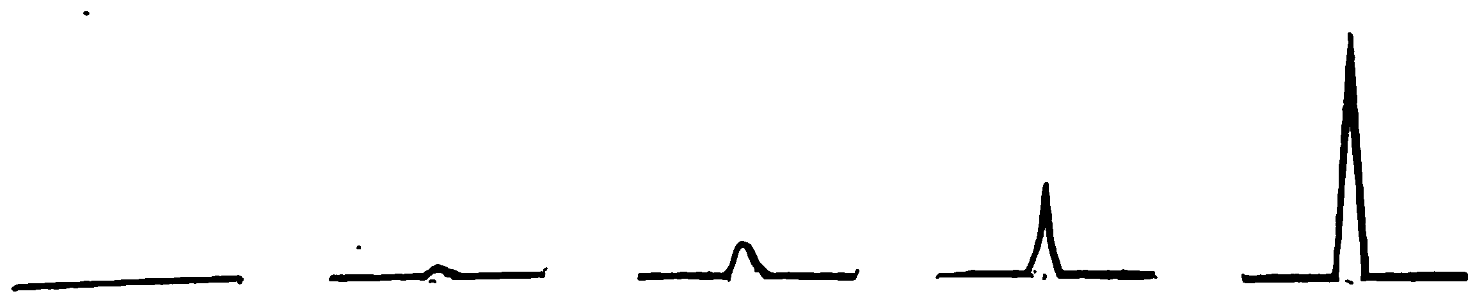
In nearly all classes of organisms, spines have been developed independently, and simply represent cases of parallel development of similar structures or morphological equivalents. They possess analogy of form without necessary homology of structure, and accordingly have no common phylogenetic connection. Therefore, if the relationships between the smooth and spinose forms belonging to any group of animals or plants can be traced, and the simplest and most primitive condition in each case, as well as the highest stage of progressive development, can be ascertained, their relative significance from an evolutionary standpoint may be confidently determined.

Growth of a Spine.

The growth of a spine is either direct and progressive, or indirect and regressive. It is direct when it is developed by the addition of new tissue. In this way, growth is attained in the antlers of a Deer, the horns of a Cow, the ordinary spines of Brachiopods, Mollusca, and Crustacea, and in other similar examples covering the majority of cases. Growth is indirect, however, when the spine represents atrophy or suppression of an organ through the loss of its accessory parts, as in the thorns of the Locust and the Barberry, the spiniform termination of the stems of the Pear, or the spurs on the Python.

The direct development of a spine is essentially the same process in all cases. At a given point on the surface of an organism, there first appears a slight elevation, which becomes higher and higher, and is usually conical in form. This cone represents the simplest type of spine; and among animals and plants, most spines conform to this primitive pattern (figures 1–5).

Often there are various kinds of surface ornaments, which by growth and differentiation develop into spines. By rhythmic, alternating areas of accelerated or retarded growth, the



FIGURES 1–5.—Different stages in the growth of a spine. 1, plane surface; 2, slight elevation; 3, node; 4, short spine; 5, completed simple spine.

concentric laminæ on many molluscs may produce spines, as shown in figure 26. In the same way, the radiating ridges may be diversified into a row of spines, as represented in figure 6. Further, the surface may be reticulate, with longitudinal and transverse lines, and at the points of intersection, nodes and often spines are formed after the manner shown in figures 7–12. The longitudinal or vertical lines may become obsolete, leaving the spines to be borne on the transverse or horizontal lines (figure 10). In other cases, the horizontal lines disappear, leaving the spines on the vertical lines (figure 11). Finally, both horizontal and vertical lines become obsolete, and then only the spines remain, as shown in figure 12.

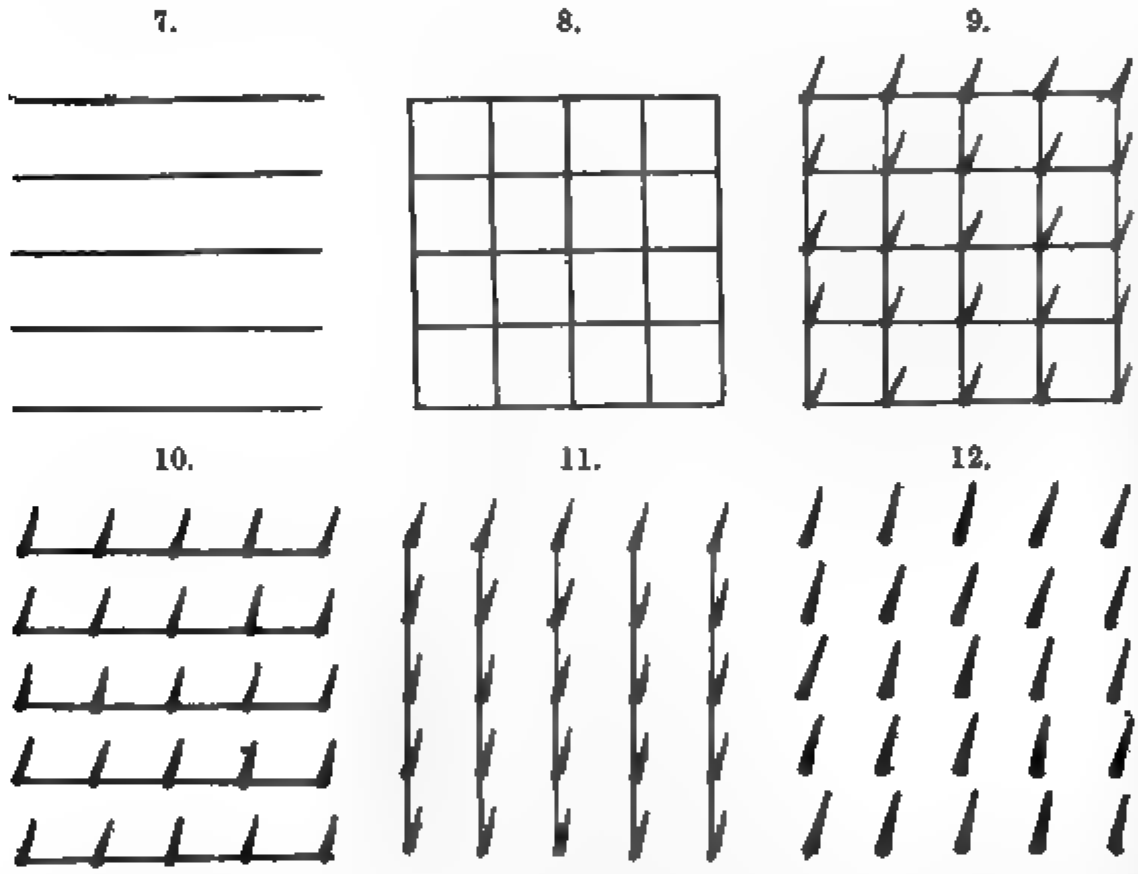
6.

FIG. 6.—A profile of a single radiating ridge of *Spondylus princeps*, showing the series of flattened spines.

The indirect production of spines is not always evident, for if the ontogeny or phylogeny of the individual is unknown, its direct or indirect development cannot be determined. An excellent example of indirect, or regressive, growth of spines is afforded in the common Barberry (*Berberis vulgaris*), on the summer shoots of which are shown most of the gradations "between the ordinary leaves, with sharp bristly teeth, and leaves which are reduced to a branching spine or thorn. The fact that the spines of the Barberry produce a leaf-bud in their axil also proves them to be leaves"[24] (figure 13).

It should be noted that the process of spine development illustrated in *Spondylus* (figure 14) is directly opposed to that of the Barberry. In the former, the initial growth is smooth, then faint concentric and radiating lines appear, which gradually grow stronger, developing more or less regular inequalities; and by the excessive growth of these variations, spines are formed. In the Barberry, there are at

first normal leaves, which are followed by others more and more toothed and bristly, until the leaf is represented by a branching spine, while finally spines only are formed. The *Spondylus* represents a progressive increase in growth to produce the spines, while the Barberry exhibits a progressive



FIGURES 7–12.—Diagrams showing growth and differentiation of ornament into spines. 7, surface with parallel lines; 8, surface with regular reticulate lines; 9, same, with spines developed at the points of intersection, 10, same, with the vertical lines obsolete, but still represented by the vertical rows of spines; 11, same, with the horizontal lines obsolete, but still represented by the horizontal arrangement of the spines; 12, same, with all lines obsolete, but both series represented by the vertical and horizontal arrangement of the spines.

decrease of growth, or an "ebbing vitality," as it has been termed by Geddes.[20]

The spines are the final results of both the direct and indirect modes of production; the direct, through a process of building on new tissue, and the indirect, through a process of dwindling away to all but the axial elements. These differences are graphically expressed in figures 13 and 14.

Attention should be called to the four kinds of spine production in different organisms. (1) In the Radiolaria, Echinoids, the Giraffe, Cattle, and the Rhinoceros, the spines or horns are persistent, and grow by additions to the original structure. The new tissue may be superficial, subterficial, interstitial, or formed by synchronous resorption and growth. (2) In the Crustacea and Articulata generally, and in the Deer,

Elk, etc., the spines are moulted, or shed, periodically. In their various stages, these types (1 and 2) can be studied only by means of separate specimens consecutive in age, or by observing the metamorphoses in one individual. (3) In the shells of Brachiopods and Mollusca, the stages of growth of the individual are generally retained throughout life, and the

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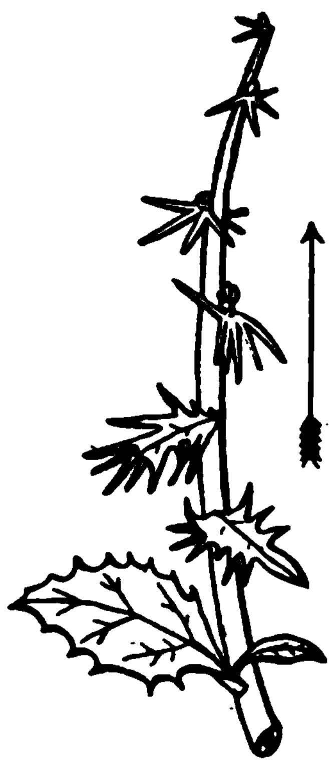

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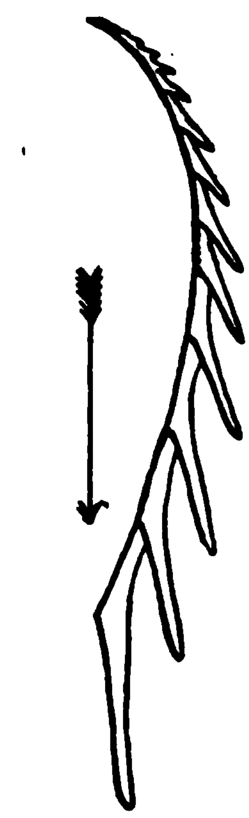

FIGURE 13.—Summer shoot of Barberry, showing the gradations between leaves and spines. The arrow indicates the direction of growth. (After Gray.)

FIGURE 14.—Profile of one of the primary rays of *Spondylus imperialis*, showing the series of spines. The arrow indicates the direction of growth.

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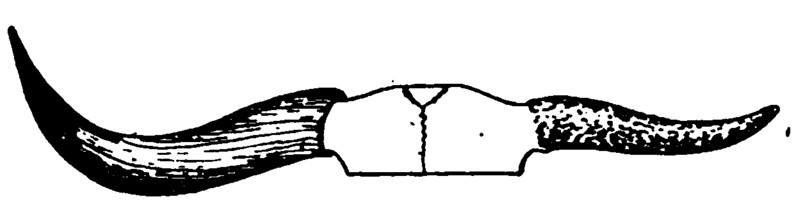

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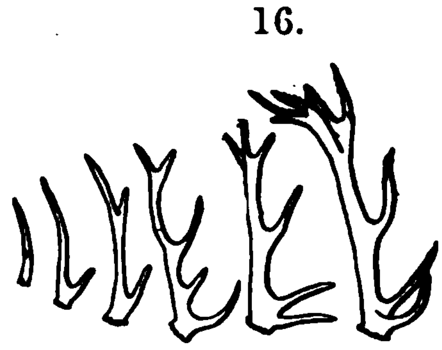

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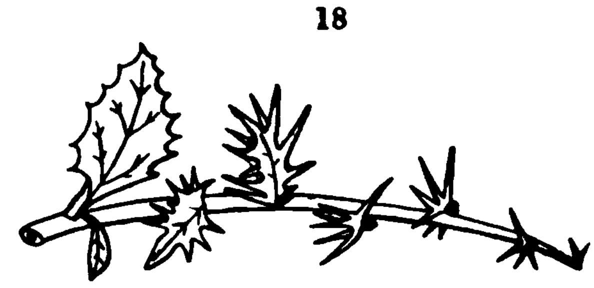

FIGURE 15.—Example of spine growth by simple increscence. Horn (left) and horn-core (right) of Ox. (After Owen.)

FIGURE 16.—Stages of spine growth by successive replacement. Antler series of Red Deer, at ages of 1, 2, 3, etc., years. (After Owen.)

FIGURE 17.—Stages of spine growth by serial repetition. Profile of a series of spines on one of the primary radii of *Spondylus imperialis*.

FIGURE 18.—Stages of spine growth by decrescence. Transformation of leaves into spines in *Berberis vulgaris*. (After Gray.)

successive development of spines may be studied, therefore, in a single example. (4) Spines produced by suppression, as in the Barberry, express their origin through a series of gradations between separate parts; while in others, suppression is brought about by the loss of structures.

The first type mentioned develops horns or spines by simple increscence (figure 15); for example, the Ox: the second, by successive replacement (figure 16); as in the Deer: the third, by serial repetition (figure 17); for example, *Spondylus:* the fourth, by decrescence (figure 18); for example, the Barberry.

Localized stages of growth.—By the multiplication of surface ornaments through the process of interpolation, many Mollusca present stages of spine development in two directions. (1) The normal series is represented by the succession of spines along a

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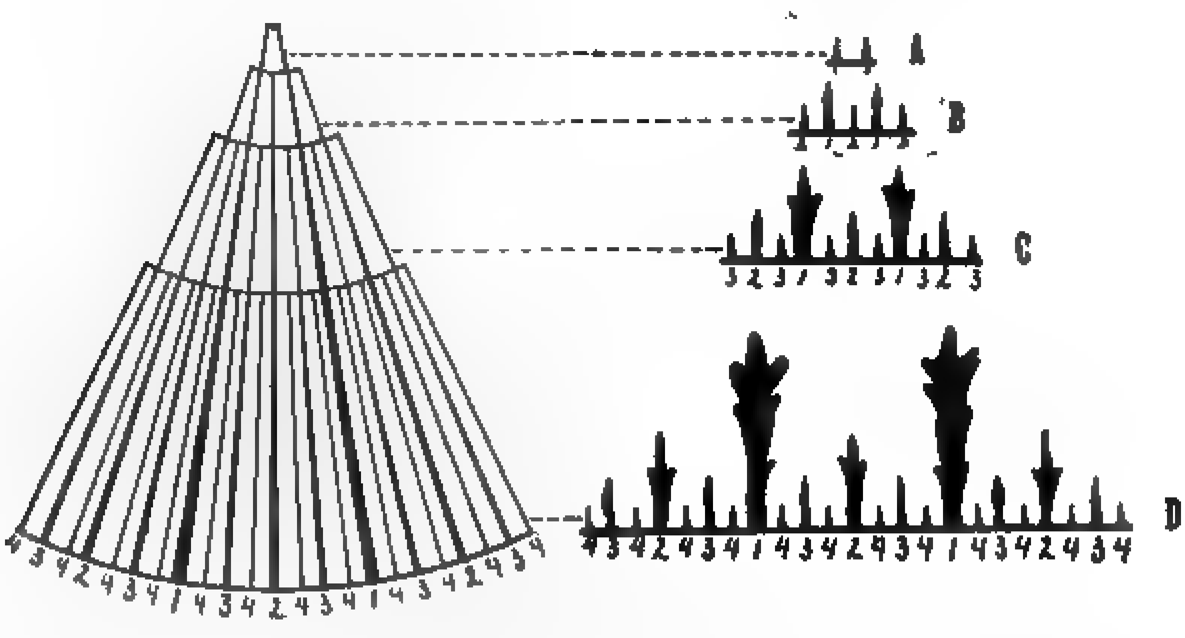

FIGURE 19.—Sector showing in diagram the multiplication of radiating lines by interpolation. The two primary radii (1, 1) are the only ones continuing through the whole four zones. The first zone has 2 radii; the second, 5; the third, 11; and the fourth, 23.

FIGURE 20.—Profiles of the spines produced on the various radii at the four zones, as indicated in the preceding figure. A, the spines on the two primary radii of the first zone; B, the spines on the second zone, showing the growth of those on the two primary radii (1, 1), and the small spines on the newly interpolated radii (2, 2, etc.); C, the spines on the radii in the third zone, D, the spines at the bottom of the fourth zone. The two large compound spines are on the two primary radii. Their development may be traced by following them through A, B, C, to D. The next three longest spines (2, 2, 2) are tricuspid, and represent the stage of spine development attained by the spines on the radii which were interpolated on the second zone. The next six smaller spines (3, 3, 3, etc.) are on radii which were introduced on the third zone. The twelve small spines (4, 4, 4, etc.) are on the radii introduced on the fourth zone. Thus there are four stages of spine growth shown on the lower margin of the fourth zone, and these correspond to the four stages exhibited by the series of spines on one of the primary radii running through the four zones.

single sector of growth. For instance, in the radial plications of a *Spondylus* or *Lima*, the earliest and primitive spines are found near the beak, while those on the ventral border of an adult specimen are the latest and most highly developed (figure 30). These successive stages, therefore, are in the direction of growth, and may be called longitudinal. (2) By the radial divergence of the ribs or plications and the interpolation of additional ones at various intervals, as many transverse compound series of spines finally appear along the periphery as there are primary radii. Hence, in a given case, there may be two radii continuing to the beak, then by interpolation there are successively 5, 11, 23, etc., radii, the highest number being found at the periphery (figures 19, 20). Moreover, by taking the distal spines on these 23 rows, there result the same stages of spine development as shown in the longitudinal series along any primitive plication (figure 20). A Pelecypod shell like *Spondylus* is here used to illustrate this process, but the application may also be made to the Brachiopods as well as to the conical non-coiled Gastropods. In a coiled form like a Cephalopod or an ordinary Gastropod, the longitudinal lines would follow the whorls spirally, and the transverse lines would correspond to the lines or increments of growth of the shell. Species in which the radii are all introduced at an early stage of growth (many species of *Cardium*, *Pecten*, *Lima*) or in which the radii multiply by regular dichotomy would show, of course, only the longitudinal series, for at the margin of the shell, the radii would be of the same size and age, and the spines uniform.

The foregoing example illustrates an important principle of ontogeny; namely, that in organisms which repeat various parts during their growth, these parts will develop or pass through a series of stages corresponding to the initial and subsequent stages of the parts repeated. In this way, structures appearing late in the ontogeny of the individual will present primitive infantile and adolescent characters. Further development, if such takes place, will pass through a progressive series of ontogenetic changes, and if the stages of growth are by serial repetition and thus are retained in the part, it will be found that such stages can be correlated with those appearing early in the life or history of the individual. Therefore, in studies of this kind, it is possible to take a structure appearing at maturity, and from it deduce or predicate as to what were some of the early characteristics of the whole individual. This principle is termed localized stages of growth by Jackson[37], and was first noticed by him in some investigations on Echinoderms.

Compound Spines.

A simple, sharp, conical process expresses only the primitive type of spine. In plants and animals, it is the most common form found, and is the first stage of spine differentiation. From this type, the myriad forms of spines known in the organic world are produced by almost insensible gradations. It is needless to attempt a detailed description of this infinite variety; but, as a single illustration, some of the leading forms of spine differentiation among the Radiolaria are here shown (Plate I). These figures are taken from Haeckel's "Report

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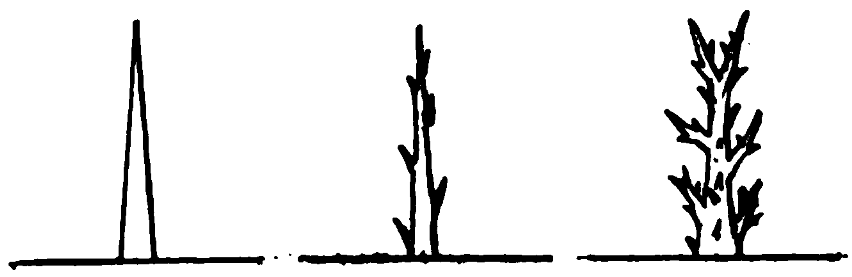


FIGURE 21.—Simple spine.
FIGURE 22.—Spine, with lateral spinules.
FIGURE 23.—Spine, with forked apex and lateral spinulose spinules.

on the Radiolaria,"[26] and generally represent enlargements of from 100 to 400 diameters.* Probably no other class of

* EXPLANATION OF PLATE I.

Spiniform processes of recent Radiolaria taken from the shells of the following species:

Fig. 1.—Heliosphæra coronata.
Fig. 2.—Astrosphæra stellata.
Fig. 3.—Astrophacus solaris.
Fig. 4.—Stylosphæra calliope.
Fig. 5.—Heliodiscus glyphodon.
Fig. 6.—Pripodictya triacautha.
Fig. 7.—Pleuraspis horrida.
Fig. 8.—Hexacontium sceptrum
Fig. 9.—Acanthosphæra clavata.
Fig. 10.—Acanthosphæra clavata.
Fig. 11.—Cromyodrymus quadricuspis.
Fig. 12.—Hexacontium clavigerum.
Fig. 13—Orosphæra horrida.
Fig. 14—Staurocyclia phacostaurus.
Fig. 15.—Tripospyris capitata.
Fig. 16.—Archipera cortiniscus.
Fig. 17.—Tripospyris conifera.
Fig. 18—Orosphæra serpentina.
Fig. 19.—Staurolonche pertusa.
Fig. 20.—Astrosphæra stellata
Fig. 21.—Staurodictya elegans.
Fig. 22.—Hexastylus contortus.
Fig. 23.—Stephanospyris excellens.
Fig. 24.—Podocyrtis magnifica.
Fig. 25.—Hexancistra mirabilis.
Fig. 26.—Dictyophimus Cienkowskii.
Fig. 27.—Elatomma juniperinum.
Fig. 28.—Castanura tizardi.
Fig. 29.—Pleuraspis horrida.
Fig. 30.—Staurocarynum arborescens.
Fig. 31.—Rhizosphæra serrata.
Fig. 32.—Phænocalpis petalospyris.
Fig. 33—Aulospathis bifurca.
Fig. 34.—Aulographis bovicornis.
Fig. 35.—Aulographis ancorata.
Fig. 36.—Aulographis bovicornis.
Fig. 37.—Sphærozoum verticillatum.
Fig. 38.—Cladococcus pinetum.
Fig. 39.—Hexancistra triserrata.
Fig. 40.—Cladococcus stalactites.
Fig. 41.—Hexancistra quadricuspis.
Fig. 42.—Heliodrymus ramosus.
Fig. 43.—Heliodrymus dendrocyclus.
Fig. 44.—Aulographis pandora.
Fig. 45.—Cladoscenium ancoratum.
Fig. 46.—Cladococcus scoparius.
Fig. 47.—Auloscena penicillus.
Fig. 48.—Circostephanus coronarius.
Fig. 49.—Lychnosphæra regina.
Fig. 50.—Auloscena spectabilis.
Fig. 51.—Cœlospathis ancorata.
Fig. 52.—Octodendron spathillatum.

organisms presents greater variety, and many of the forms are repeated again and again, not only in various species of this group, but elsewhere both in the animal and vegetable kingdoms.

Whenever the development of a compound spine can be studied, it shows a gradual progress from the simple to the complex (figures 21–23). The antlers of the Red Deer (*Cervus elaphus*) furnish a familiar example. Fawns of the first year have antlers with only a single prong, a short front tine being added the second year; then "year by year as they are renewed they acquire a greater and still greater number of tines and branches, till they finally attain the complete stage, when their owner is termed a 'royal hart'"[44] (figure 16). Although somewhat conventionalized, the primary series of spines on the *Spondylus* shown in figure 20 exhibits the passage from simple to compound forms. An inspection of many species of *Murex* will show the stages in series presenting a greater complexity.

After spine development has reached its maximum growth and differentiation, evidence of old age may be exhibited in two ways: (*a*) The spines may be reduced by resorption, decay, or abrasion, and finally become obsolescent; or what is of greater import (*b*), they may gradually cease to be developed, as is especially shown in organisms in which spine growth is by serial repetition. Thus, in *Spondylus calcifer*, a young individual measuring about two inches across has marginal spines fully an inch in length. Even longer spines are found when the shell reaches a width of four inches. On attaining a maximum diameter of about six inches, spine growth gradually ceases, and the margin of the valves is entire and nearly smooth. At this stage, shell secretion is confined to excessive thickening of the valves. These senile stages of spine growth will receive further consideration under the discussion of ontogeny and phylogeny of spinous species.

Application of law of morphogenesis.—The manner in which spines arise from plane surfaces, or from the growth or modification of superficial structures, and also through the decadence of organs, has now been noticed. The spine may thus be taken as a unit for comparison, and its various stages of growth, which were shown to have a definite sequence, may be used in correlation to determine relatively the degree of spine specialization attained by any organism. Furthermore, enough data have been already given to lead to the suspicion that spines may represent the limits of ornamental or superficial differentiation or variation. At this point in the discussion, this statement must be considered as more suggestive than

conclusive. The proof of its reality will be more clearly shown later on.

Ontogeny of a Spinose Individual.

With few exceptions, the embryonic and larval stages of all organisms are devoid of specialized surface features. In other words, they are without ornament and without weapons. The exceptions to this rule seem to be readily explained under the principles of larval adaptations and accelerated development. Cases of the latter kind, therefore, can hardly be considered as exceptions, since they represent, not real larval features, but former adult characters which have been pushed back or which develop earlier so as to appear eventually in the larval or later embryonic stages. In the very earliest stages of embryonic development, the truth of the first statement becomes obvious, and accordingly the protembryonic, mesembryonic, metembryonic, neoembryonic, and typembryonic stages are without surface ornaments or spines.

Among Mollusca, the protoconch, periconch, and prodissoconch, or the early larval shells, are smooth and without ornament. Even the prodissoconch of very highly spinose species, as in *Spondylus*, is as smooth as that of the plainest species of *Ostrea*, *Anomia*, *Avicula*, etc. Likewise, the protoconch of the most specialized or most retrograde Cephalopod is perfectly plain. In the nepionic stages, the spiny *Murex* is without spines. In the Brachiopoda, the protegulum, or early larval shell, is always without sculpture; while the nauplius of Crustacea and the protaspis of Trilobites are generally spineless. The young of horned vertebrates are almost universally hornless, the Giraffe being the only mammal born with horns. The very young seedlings of plants are likewise spineless. In insects, the embryonic stages generally have simple cuticles, but in the larval stages of this class and the Crustacea, a great variety of spines and ornamental characters is developed. Altogether, it may be asserted that spines do not appear during the embryonic stages of animals and plants, and that their initial development is commonly post-larval.

Examples illustrating the ontogeny of a spinose form could be multiplied indefinitely, and taken from nearly every class of organisms. In all cases, practically the same sequence of events relating to the development of spines would be found. The organism would first be smooth, without sculpture or ornament, like the young of other organisms. At some stage of the ontogeny, the beginnings of spines would appear, and develop first into simple, and later, according to the stage of differentiation attained, into compound spines. This progression would finally reach the maximum, spine growth would

cease, and the surface of the organism would inversely revert to an early and more primitive type without spines. Normally, these changes would represent the infantile, adolescent, mature, and early and late senile periods of the life of the organism. In some cases, however, the stages of spine growth, or acanthogeny, do not agree with the ontogeny of the entire individual in respect to time, and here acceleration and the phylogeny of the species will be found to offer the proper explanation of the divergence.

As simple examples of the ontogeny of spiniferous species, the Mollusca afford especial advantages, owing to the fact already noticed, that the stages of development are commonly preserved in a single individual. In figure 24, the larval shell, or prodissoconch, of Pelecypods, or bivalve shells, is represented, and shows the usual type throughout a large portion of the class. The succeeding shell growth of the dissoconch is at first generally smooth, save for the fine concentric lines of growth (figure 25). In ornamented or spinose species, however, irregularities in the growth lines soon appear (figures 26, 27), and these shortly assume the characteristic surface sculpture of the normal adult. Thus, the prodissoconch of *Avicula sterna* is represented at *p*, figure 25, and is followed by regular concentric growth during the nepionic stages. In figure 26,

24. 25. 26.

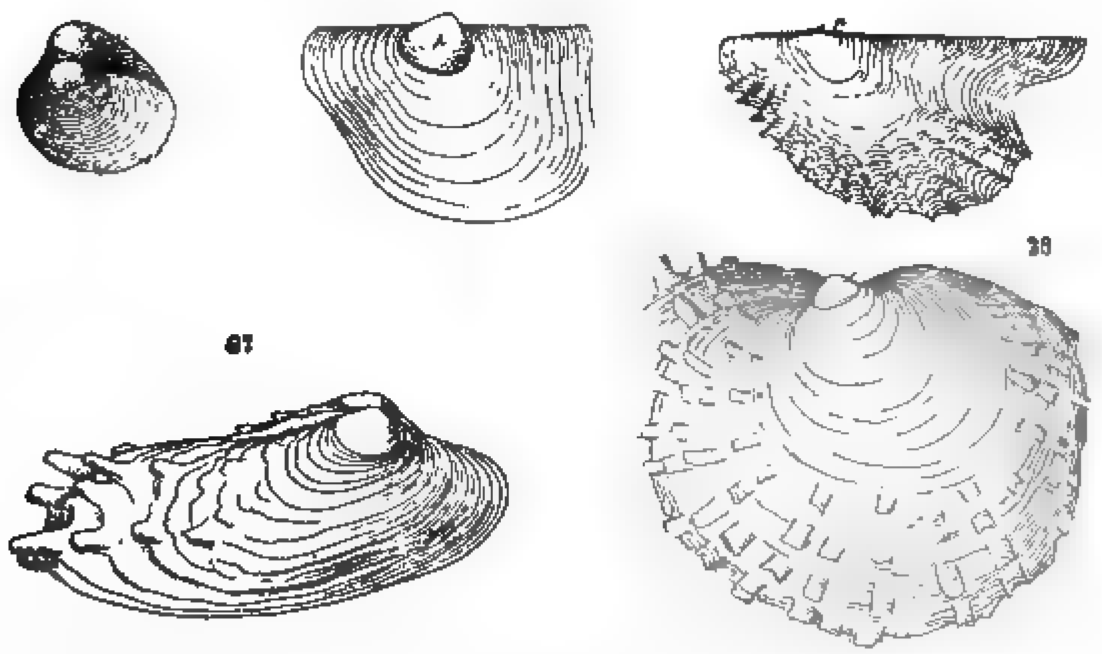
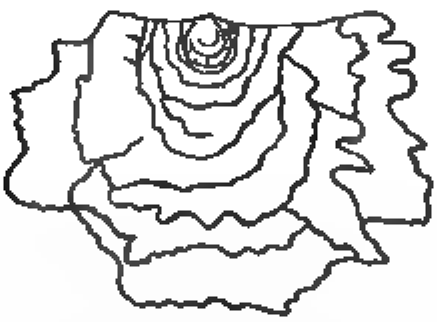


FIGURE 24.—Prodissoconch of *Ostrea virginiana*. × 43.
FIGURE 25.—Each stage of *Avicula sterna* ; *p*, prodissoconch × 19
FIGURE 26.—Young *Avicula sterna*, showing the beginning of spine growth. × 3.
FIGURE 27.—Young *Saxicava arctica*. × 19.
FIGURE 28.—Young *Anomia aculeata* ; *p*, prodissoconch succeeded by early smooth and later spinous dissoconch growth. × 30 (24–28 after Jackson.)

the spiny characters of early adolescence are added to the previous stages, and in later stages, the spines become more and more emphatic.

In *Spondylus*, the prodissoconch is the same simple form, and is succeeded by a nearly smooth Pecten-like stage, during which the animal was free (figure 29). After fixation, the growth is very irregular and ostræiform for a time, until the shell rises above the object of support, when all the most characteristic features of surface ornamentation become fully developed (figure 30). As the shells approach maximum growth, the spines gradually become shorter, and in old age, none are developed, even those of early growth being removed by the action of boring animals and by solution (figure 31).

29.



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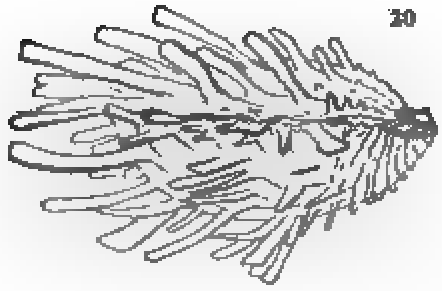


31.

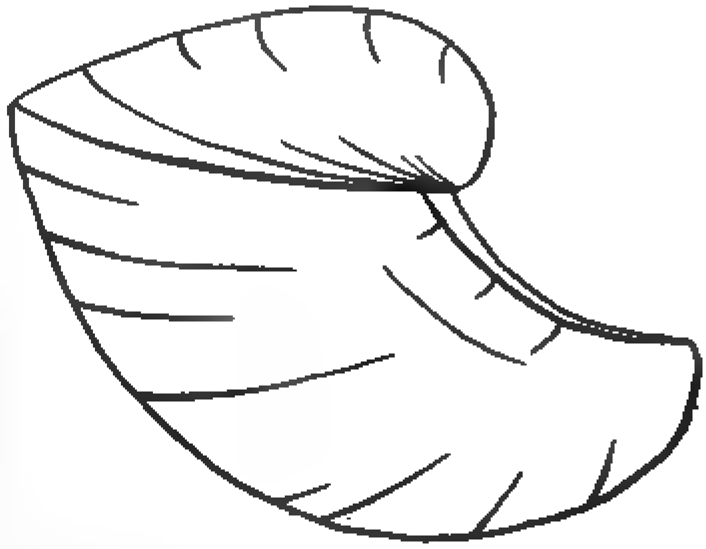


FIGURE 29.—Young *Spondylus princeps*. Right valve, showing pecteniform stage succeeded by ostræiform growth. Taken from apex of adult specimen; presented by R. T. Jackson. × 3.

FIGURE 30.—Side view of *Spondylus calcifer*, about one-third grown, showing the characteristic spinous growth. ½.

FIGURE 31.—Side view of *Spondylus calcifer*, showing the greatly thickened right valve and the entire absence of spines over the whole shell. ½.

It seems unnecessary to increase the number of examples showing the ontogeny of spinose individuals. The Deer and the Ox may be again cited in this connection. Both are born without horns, but during adolescence, the antlers of the Deer become longer and more complicated with each renewal, while the horns of the Ox are longer and more twisted. In old age, when the Deer has passed his prime, the antlers are more obtuse, and exhibit a tendency toward decline and obliteration. Suppression of the antlers is accomplished by the removal of the cause of antler growth and specialization, so that the

unsexing of the male results in small antlers, which are seldom branched, and become thickened by irregular deposits of bone (Owen[53]). Spines grow during the adolescence of the Horse-Shoe Crab, *Limulus polyphemus*, yet in old age they are obsolescent, being represented by rounded nodes.

As examples illustrating the accelerated development of spines in widely separated classes, the Giraffe among mammals and *Acidaspis* among Arthropods may be selected. The Giraffe represents the continuance of a very primitive type of horn; namely, one covered with a hairy skin. They are never shed, and are common to both sexes. Out of this type, all others found among the Mammalia have probably been developed. The point of interest here is that the young Giraffe is born with horns, and as these could serve no prenatal purpose, it must be concluded that the action of accelerated heredity has pushed the development of these organs so far forward as to cause them to appear during fœtal growth.

The next illustration of acceleration is taken from the Trilobites. *Acidaspis* is one of the most highly specialized and ornate genera. Although the larval forms of other genera are commonly without ornament, yet in the present genus, the protaspis, or phylembryonic, stage partakes of this specialization in so far as to develop minute spines, which later become larger, more differentiated, and form a conspicuous feature of the adult. Other characters have been likewise shown to appear at an earlier period than in other genera, and the earlier inheritance of spines must be explained in the same manner.[8]

The facts, as stated, seem to warrant the conclusion, that in spinose organisms, the very young are almost universally without spines. Acceleration may occasionally push their development into the embryonic and larval stages, but ordinarily they are not so subject to the action of this law as are some of the physiological and other structural characters. This will be explained as in part due to the lack of general plasticity, and because differentiated spine growth is the progressive limit of variation. Therefore, there are no subsequent characters to displace them and crowd them forward in the ontogeny.

Phylogeny of Spinous Forms.

To interpret phylogeny in terms of ontogeny, according to the law of morphogenesis, or recapitulation, is perhaps easier than to trace a genetic sequence through a series of forms having a considerable geologic range. Taking the ontogenies of the animals already noticed, there is for the Pelecypods the prodissoconch, which is correlated by Jackson[36] with *Nucula*, and a Lower Silurian nuculoid radicle is assumed for the

Aviculidæ and allied forms. The first dissoconch growth produces a shell resembling *Rhombopteria*, a Lower and Upper Silurian type, and this is taken to represent the second stage in the phylogeny of *Avicula* (figure 25), *Anomia*, *Spondylus*, etc. Continuing the development of *Spondylus*, it is found by Jackson that it passes successively through stages which may be correlated with *Pterinopecten* (Devonian), *Aviculopecten* (Devonian), *Pecten* (Carboniferous ?), and *Hinnites* (Trias), while finally it assumes true spondyliform characters. These correlations agree with the geologic sequence of the genera, and are believed to indicate phylogenetic relationships. It may be further remarked that the early species of Spondyli are more truly pecteniform and hinnitiform than the later ones. The genus ranges from the Trias to the present. Zittel[73] remarks that "the oldest species are small, thin-shelled, and seldom much ornamented." Even in the Cretaceous, the majority of species are not far removed from *Pecten* and *Hinnites*. During the Tertiary, the irregular, ostræiform, squamous, concentric, and spinous growth becomes more manifest, and at present most of the species show a great development and differentiation of the spines.

Thus, while *Spondylus* is normally considered as a spinose genus and the species are familiarly known as Spiny Oysters, yet as it is traced back in geological history, the forms become less and less spinose, and their affinities and appearances are more and more in accord with non-spinose genera, until finally the prototype is a smooth, simple, delicate, unornamented shell.

The simple antlers of the young Deer and Elk correspond in type with those of the adults of the Middle Tertiary Deer (Lydekker[44]), and it may be therefore assumed that the great number of branches and tines is a modern development. Further back in the Tertiary, the ancestors of the Deer were without antlers, thus representing in phylogeny the new-born Deer of the living type. These correlations are made from comparisons of chronogenesis, or development in time, and ontogenesis, or development in the individual.

An example of a different kind will now be given to show more clearly a genetic sequence in forms. Among the Brachiopods, *Atrypa hystrix* represents one of the terminal members or species of a line of varietal and specific differentiation, extending through the Silurian and Devonian. The type commonly known as *Atrypa reticularis* appears to have had its inception during the Ordovician; yet in the Silurian, it is found as a conspicuous and fully developed form. Here, also, it has quite a wide range of variation, but there seems to be an insensible

gradation between the extremes, which, therefore, cannot be considered as definite permanent varieties. There are, however, associated forms that have received distinctive specific names, which do not shade into each other. During the early and middle Devonian, certain of these variations in the main stock of *A. reticularis* became more fixed, and at the time of the Hamilton sediments in New York, there are two forms known as *A. reticularis* and *A. aspera*, which apparently do not pass into each other. As time went on, these two types became more specialized and the divergence correspondingly increased, until in the Upper Devonian, in the Chemung sediments, there is a large many-plicated *A. reticularis*, as well as a form with very few plications and long marginal spines, *A. hystrix*. Hall and Clarke[31] thus summarize the stages leading to the formation of the spinose forms: "In the variant of *Atrypa reticularis*, occurring in the Niagara fauna at Waldron, Indiana, the free concentric lamellæ frequently show a tendency to fold inward at the summit of the principal plications. The infolded edges fail to unite, and this tendency to the formation of tubules is apparently carried no further at this period. More extreme results were attained by the *Atrypa aspera* of the Hamilton shales, or possibly by its migrated ancestor, during the period of time represented by the deposition of the Lower Helderberg, Oriskany, and Upper Helderberg sediments. At all events, the *Atrypa spinosa* of the Hamilton shales is but an *A. aspera* with the lamellæ enfolded into tubular spines. Intermediate stages connecting these different phases are not present in this fauna." . . . . "This spinose form is continued into the Chemung faunas (*A. hystrix*), with some modification of expression, the spines being few and long, and the plication of the surface very coarse and quite simple; the shell in its decline thus representing a decided return to the primitive type of structure." H. S. Williams[72] has classified the variations in the stock of *A. reticularis* as to whether differentiation in the number of plications is increased or retarded, and concludes that the extremes are most strongly expressed at the close of the life-period of the race. The numerously plicated type represents the accelerated phase of the multiplication of radii, while *A. hystrix*, with its few and coarse radii, represents the retardation or suppression of this tendency.

The only great group of animals receiving its name from its characteristically spinose surface is the Echinodermata, or the spiny-skinned animals; yet it is extremely doubtful whether this name would have been used had the first studies of the group been based upon the Paleozoic representatives,

especially the pre-Devonian species. The early Sea-lilies (Crinoidea), Cystideans (Cystoidea), Blastoids (Blastoidea), and Star-fishes (Asteroidea) had smooth or nearly smooth integuments. In its early genera, even the most typically spiny class of the whole sub-kingdom, the Echinoidea (Sea-urchins) had very minute and insignificant spines. It is only in the late Devonian and in the Carboniferous that truly spiny forms of Crinoids, Star-fishes, and Sea-urchins are found.

Of equal significance is the fact that the Echinodermata together with the plants represent the most primitive type of structure, one in which there is a more or less circular arrangement of the parts or organs. The Echinodermata are the highest development in this line of growth among animals. They culminated in past geological ages, and from them no direct line of descent can be traced (Bailey[2] and Cope[11]).

The conclusion from the study of the phylogenies of spinose forms is parallel to the one drawn from the ontogenies; namely, that the ancestors of spinose as well as non-spinose organisms were simple and inornate.

[To be continued.]

ART. II.—*Electrical Discharge from the point of view of the Kinetic Theory of Matter*; by J. E. MOORE.*

PART I.—ON THE NATURE OF DISCHARGE STREAMS.

§ 1. *Introductory Remarks.*

IT is proposed in the present paper to consider some notions concerning the elementary nature of electrical discharge in gases, which are almost wholly dependent upon the kinetic theory of matter.

However, before beginning, I wish to state that, as these notions are not in all respects in complete agreement with conclusions reached by some of the Continental and English physicists, I desire to bring them forward with considerable reserve, and with the greatest deference to the opinions of those eminent physicists, who having, perhaps, worked under different conditions, look upon these matters somewhat differently.

In order that these notions may be presented in their more general relation to phenomena, other than those of electrical discharge in gases, it is desirable to review briefly some well known facts.

In the first place it may be mentioned that the physical state of a body of gas is completely defined when we know, for that gas, its (internal) energy, entropy, volume (of a definite mass of the gas), pressure, and temperature. Three of these thermodynamic variables can be, and properly are, regarded as dependent upon the other two. So that the physical state of a body of gas is said to depend only upon its temperature and pressure.

If it be possible to consider electrical discharge through a gas as a function of the thermodynamic variables of that gas it must necessarily follow, that the phenomena of electrical discharge will be found to be dependent only on the temperature and pressure of the gas; or, since in almost all electrical experiments the temperature is kept constant, for this functional relation to exist, electrical discharge phenomena must be found to be dependent only on the pressure (or the molecular density) of the gas. This, as is well known, is actually the case. So that if we place a pair of electrodes in such a gas as air, at atmospheric pressure, discharge can only take place between them disruptively; and, as the pressure of the gas is made to vary continuously, the phenomena of electrical discharge are seen to vary continuously from disruptive discharge at atmos-

* Part I presented to the Faculty of Princeton University for the degree of Doctor of Science, June, 1898.

pheric pressure, to the total cessation of discharge at the lowest pressures attainable.

It is not intended in this paper to describe in detail the constantly changing phenomena accompanying electrical discharge, as the pressure of the gas is made continuously to vary. It may be stated, however, that disruptive discharge ceases at a pressure only a little below atmospheric, and, at a pressure of a few centimeters of mercury, the discharged path is seen to be broken up into a series of dark and bright striæ. It is worthy of special mention that the pressure at which this stratification phenomenon makes itself apparent in any particular tube, depends only on our ability to separate (optically) a bright and a dark line, and that, with steady potential differences, one can distinguish the striæ much earlier, by using a proper magnifying glass. This fact will be considered more fully farther on. The distance between consecutive striæ increases continuously, while the bright and dark bands broaden until (in a tube with fixed electrodes), the bright band of the last remaining stria comes to coincide with one electrode, and the dark band with the other.

Almost immediately after the disappearance of the stratification phenomenon, a column of blue light is seen to proceed from the negative electrode. At its first appearance, this cathode stream covers the whole surface of the negative electrode, but, as the pressure of the gas is reduced, the area covered becomes less and less, until finally, at a pressure something less than one-millionth of an atmosphere, not only has the stream come to cover a vanishingly small area of the negative electrode, but the blue light, by which the cathode stream is characterized, has totally disappeared.

With only an ordinary mercury pump we can reduce the pressure of the gas much lower than that at which the cathode stream disappears. On this further reduction of the gaseous pressure, the fluorescence of the glass walls, as well as all other evidence of electrical discharge, gradually vanishes. By absorbing the residual gas by chemical or mechanical means, such low pressures can be obtained that even though the electrodes are only a few millimeters apart no discharge can be made to pass between them, when their potential-difference is so great as to be capable of causing a spark twenty-five or thirty centimeters long in air.

By reasoning on these limiting values of electrical discharge precisely as we reason on the limiting values of functions generally, it would seem to be abundantly evident that, in space void of matter (that is in free ether), electrical discharge through that space must be zero for all possible values of the potential-difference between the electrodes.

In order to consider the character of electrical discharge phenomena a little more fully at the superior limit of pressure (or molecular density), it may be permissible to state again that the pressure at which the stratification phenomenon makes itself apparent, depends only on our ability to distinguish a dark from a bright line; that these striæ widen and grow farther apart as the pressure of the gas decreases, and conversely, become finer and more closely crowded together as the pressure of the gas increases. So that if a tube, in the stratification state, transmitting electrical discharge, have the pressure of the gas continuously increased, from a pressure at which the striæ are plainly visible to a pressure at which they can no longer be seen, one would admit that electrical discharge takes place by the same mechanism in the last state as when the striæ were visible. If the pressure be increased to atmospheric, and the discharge take place disruptively, we would admit that the type of transaction is the same as in the stratified discharge. Likewise, if we compress the gas to a liquid (and that liquid be a conductor), from considerations of the continuity of the gaseous and liquid states of matter, we ought to expect the type of transaction to remain unchanged. Finally, if we change the liquid to a solid (and that solid be a conductor), the same considerations as above would lead us to believe that conduction through this solid takes place by a type of transaction represented by stratified discharge in gases.

From this brief, general view of electrical discharge phenomena, several facts would seem to be indicated. First, that electrical discharge through a gas is primarily a transaction in that gas, and ought, therefore, to be studied from the standpoint of gas theories. Second, that the general type of electrical conduction is represented in the stratification phenomenon. Third, that the elementary mechanical actions in electrical discharge can best be studied in discharge streams. Fourth, that the study of the elementary mechanical transactions in electrical discharge is not a study merely of some interesting light phenomena, but rather a study of the elementary actions in electrical conduction, not only in gases, but in liquid and solid conductors as well.

§ 2. For a long time it has been well known that a most remarkable similarity exists between thermal and electrical phenomena. Some of the most important laws and theorems in electrical science have been developed from, or suggested by, the appropriate thermal analogies. Many instances might be cited, but one of the most striking, as well as one that illustrates how completely, even in very complex cases, these analogies hold, is the adaptation by Lord Kelvin of Fourier's solu-

tion for the flow of heat in an infinite cylinder, to the problem of the variable electric flow in submarine cables.

The mathematical theories of heat and electricity are identical in form, so that one can pass from a given theorem in the theory of heat to the corresponding theorem in electricity, by merely changing such quantities as temperature to potential, thermal conductivity to electrical conductivity, etc.

The comment that has always been made on this remarkable correspondence is, that it seems highly probable that these analogies are consequences of hitherto undiscovered relations existing between the two classes of phenomena.

The kinetic theory of gases rests upon two fundamental hypotheses. First, that matter is not a continuous plenum, but that it is made up of minute, discrete parts, which are in constant agitation. Throughout the kinetic theory, these parts are called molecules; but it is clearly stated that they are not necessarily "chemical molecules." Second, that these molecules repel one another with a force, acting in the line of their centers of gravity, whose magnitude depends upon the mass of the molecules, and on some function of the distance between their centers. In some cases, the equivalent of this last hypothesis, viz: that molecules are hard, perfectly elastic spheres, has been used to establish theorems in the kinetic theory.

From these two hypotheses, Clausius, Maxwell, Reynolds, and others, have deduced, by ordinary processes of rational mechanics, almost all the known properties of gases. Thus, according to the kinetic theory, the pressure in a homogeneous gas, at uniform temperature, is $\frac{1}{3}\rho v^2$, while its temperature is kmv^2; where ρ is the gas density, v the mean velocity of the gas molecules, m the mass of the molecules (supposed all the same), and k a constant depending on the gas.

§ 3. Maxwell has considered, in his paper, "On the Dynamical Theory of Gases,"* the pressures due to the motion of a medium composed of moving molecules. His argument is briefly as follows:

Let the medium move, with reference to a fixed system of rectangular coördinates, so that the velocity of flow referred to the three axes shall be u, v, and w. Let a second system of rectangular coördinates move with the medium, with velocity, u, v, and w. Call ξ, η, and ζ the component velocities of the motions of agitation of any molecule, when referred to this second system. The actual velocity of any molecule at any instant will then be $u+\xi$, $v+\eta$, and $w+\zeta$. The pressures in the moving medium will then be, as Maxwell has shown,

* Phil. Trans. Roy. Soc., vol. clvii, p. 49.

$$1.\ \begin{cases} P_x = \rho u^2 + \overline{\rho\xi^2} + \rho uv + \overline{\rho\xi\eta} + \rho uw + \overline{\rho\xi\zeta} \\ P_y = \rho vu + \overline{\rho\xi\eta} + \rho v^2 + \overline{\rho\eta^2} + \rho vw + \overline{\rho\zeta\eta} \\ P_z = \rho wu + \overline{\rho\xi\zeta} + \rho wv + \overline{\rho\eta\zeta} + \rho w^2 + \overline{\rho\zeta^2} \end{cases}$$

Where — above quantities signifies mean values. If we consider the gaseous medium to move parallel to the axis of X, then $v = w = 0$, and the above equations for pressure take the simplified form :

$$2.\ \begin{cases} P_x = \rho u^2 + \overline{\rho\xi^2} + \overline{\rho\xi\eta} + \overline{\rho\xi\zeta} \\ P_y = \qquad \overline{\rho\xi\eta} + \overline{\rho\eta^2} + \overline{\rho\zeta\eta} \\ P_z = \qquad \overline{\rho\xi\zeta} + \overline{\rho\eta\zeta} + \overline{\rho\zeta^2} \end{cases}$$

If $\overline{\rho\xi\eta}$, $\overline{\rho\zeta\eta}$, etc., be small in comparison with $\overline{\rho\xi^2}$, etc., and we put

$3p = \overline{\rho\xi^2} + \overline{\rho\eta^2} + \overline{\rho\zeta^2}$, equation 2 becomes,

$$3.\ \begin{cases} P_x = \rho u^2 + p \\ P_y = P_z = p \end{cases}$$

This last equation plainly shows that when gaseous matter moves in a stream in any definite direction, say that of X, the pressure of the gas in that direction is increased by an amount proportional to the square of the velocity of translation.

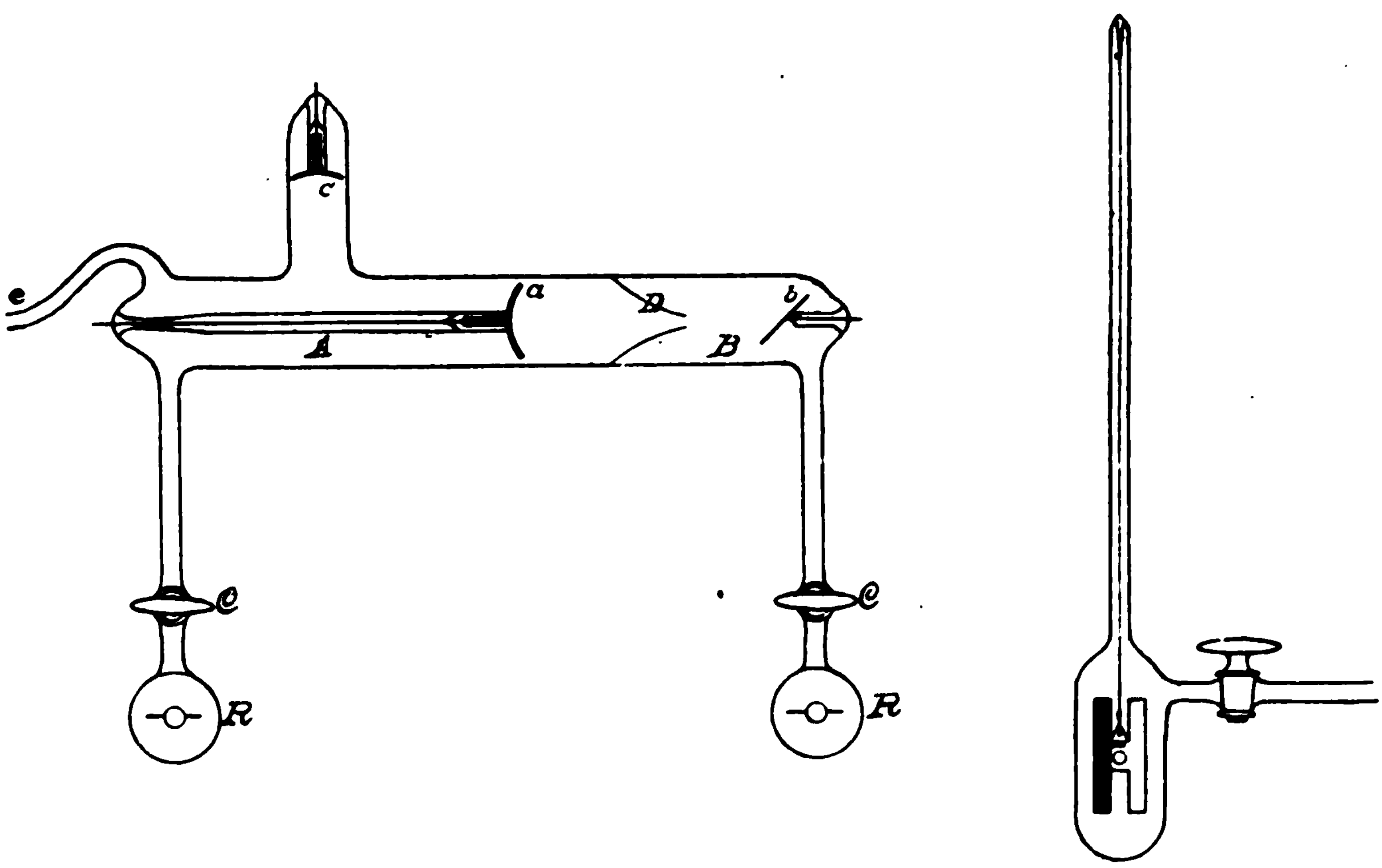
§ 4. If, in electrical discharge through a gas, the discharge stream be a stream of gaseous matter, it should be found, according to the above consideration, that the pressure in the direction of discharge is greater than in either of the directions at right angles, by an amount depending upon the velocity of the discharge stream.

In order to determine whether or not this inequality of pressure actually exists in a gas transmitting electrical discharge, an experimental tube, as described below and illustrated in figs. 1 and 2, was made.

As shown in fig. 1 (p. 26), the tube is of cylindrical form, about 33^{cm} long, and $3{\cdot}6^{cm}$ internal diameter. It is provided with three electrodes, but in the experiments to be described, only the electrodes (*a*) and (*b*) are used. (*a*) is an aluminum electrode of spherical form, $2{\cdot}8^{cm}$ in diameter, having a radius of curvature of $2{\cdot}5^{cm}$. (*b*) is a plane platinum electrode. (D) is a funnel-shaped glass diaphragm sealed to the walls of the tube around its base and having an opening of about $\cdot 5^{cm}$ at its apex. (R, R) are two similar radiometers, communicating with spaces (A) and (B) of the tube respectively; the connecting tubes from the radiometers are provided with stopcocks (C, C). One

of the radiometers is shown in detail in fig. 2. The movable vane consists of an H-shaped piece of clear mica. The two vertical members are lampblacked on opposite sides. The radiometer vane is provided with a mirror for reading angular deflections and a small magnet to give it directive force; the whole system is supported by a single cocoon fiber attached to a hook at the upper end of the suspension tube. The tube (*e*) leads to a mercury pump.

1. 2.



The radiometers (R, R) are employed for the purpose of measuring the pressure in the regions (A) and (B) respectively of the tube, and in this way serve as means for indicating whether or not, during electrical discharge, the gaseous pressures in these regions become different.

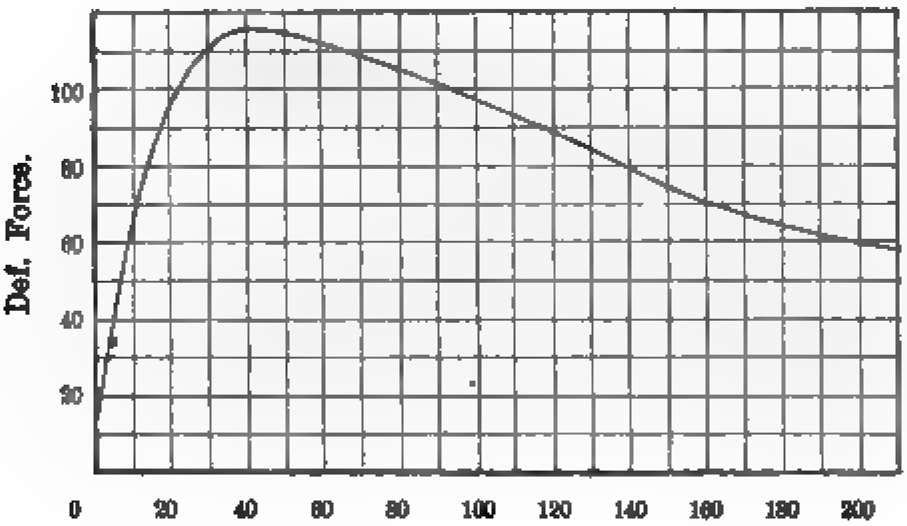
That the deflecting couple acting on a given radiometer vane (when a constant light source is used) may be taken as an indication of the pressure (or molecular density) of the gas within the containing vessel, has been shown experimentally by Crookes* and is a direct consequence of the beautiful theory of the radiometer as given by Reynolds†. Without considering the theory of the radiometer at this point, the relation existing between the gaseous pressure within the radiometer vessel and the deflecting couple acting on the radiometer vane, produced by a constant light source, is clearly shown by fig. 3, which is taken from Crookes's paper just cited.

* On Repulsion resulting from Radiation, Phil. Trans., Roy. Soc., vol. clxx, Pt. I, p. 87.

† Dimensional Properties of Matter in the Gaseous State, Phil. Trans. Roy. Soc., vol. clxx, Pt. II, p. 727.

The radiometers in the present instance were designed to be used at pressures corresponding to points lying on the sensibility curve between maximum and zero deflecting forces. The

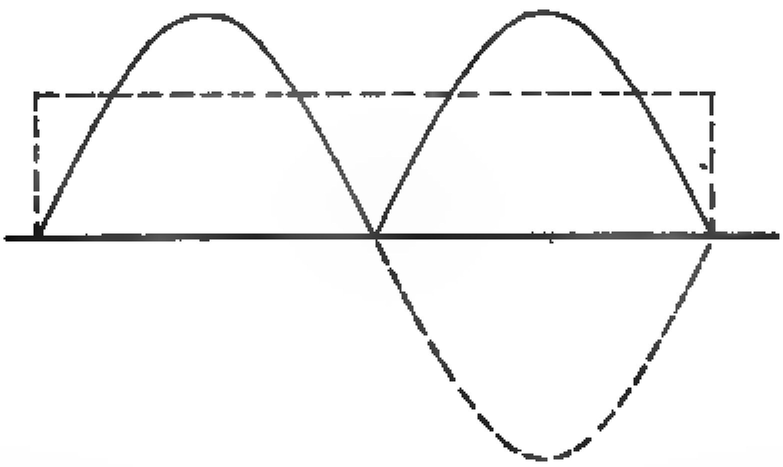
3.



reason plainly being, that on this branch of the curve $\frac{dF}{dP}$ has its maximum value,—F being deflecting force and P pressure.

On account of the somewhat uncertain, as well as intermittent character of the potential-difference produced by an induction coil actuated by a make and break in the primary circuit, it has been found most desirable and useful to employ an alternating current, varying as a simple harmonic function of the time, in the primary of the induction coil. The potential-difference thus induced in the secondary circuit is alternating

4.



in character. By employing a two-part commutator, driven by a synchronous motor, the alternating potential-difference is rectified as shown by waves above the abscissas line in fig. 4.

As the secondary of the induction coil is short circuited twice during each rotation of the two-part commutator, the potential-difference at the terminals of the secondary must be zero at the instant of short circuit, to prevent serious sparking at the contact brushes. This adjustment is easily made, and serves as a delicate means to determine when one of the electrodes of a tube, connected to the terminals of the commutator, is at every instant, throughout the waves of potential, positive, and the other electrode, at every instant, negative.

The tube, being connected to the mercury pump, is levelled and otherwise adjusted until the radiometer vanes hang centrally in their containing vessels. The whole tube is then thoroughly exhausted and dried, (the glass stopcocks C, C, fig. 1, being open). A separate light source of constant illumination is provided for each radiometer. Incandescent lamps have been found most desirable for this purpose. An image of the filiment of the incandescent lamp, as reflected from the concave mirror on the radiometer vane, is received on a white graduated scale, located between the radiometer and the light source. The pressure of the residual gas in the tube is then adjusted, by means of the mercury pump, until any further reduction of the pressure decreases the deflection of the radiometer vane. One can in this way be sure that the pressure in the tube corresponds to some point on the descending branch of the sensibility curve.

The tube is then left connected to the mercury pump, and the uni-directional potential-difference, obtained as described, is connected to the electrodes (*a*) and (*b*), fig. 1,—(*a*) being made negative, (*b*) positive. At the pressure above indicated (about $10 . 10^{-6}$ Ats.), a clean cut discharge stream is seen to go out from the negative electrode (*a*), pass continuously through the opening in the funnel-shaped diaphragm (D), strike the positive electrode (*b*), and cause fluorescence on the glass walls of the tube back of (*b*), not shielded by the electrode. The glass stopcocks (C, C) are now closed, the induction coil and the rotating commutator are thrown out of action. The images of the incandescent lamp filiments on the graduated scales are allowed to come to rest. The stopcock of the radiometer on the B-side of the diaphragm (D) is then carefully opened. The deflection of the radiometer, as indicated by the reflected image of the incandescent lamp filiment, is seen permanently to decrease. The change in deflection on opening the cock amounted in some experiments to as much as 10^{cm} when the scale was 75^{cm} from the radiometer. On opening the cock connecting the radiometer, on the A-side of the diaphragm, with the tube, very little change of deflection is noted. This is readily understood when the relative

volumes on the two sides of the diaphragm (D) are considered. The whole exhausted system of the mercury pump is in connection with the region (A) of the tube. The volume of the pump system is two or three times greater than the whole volume of the tube. So that the indication of the second radiometer merely shows that no measurable reduction in the gaseous pressure on the A-side of the tube occurred during discharge. This experiment was repeated many times, and at different pressures. In every case the indication of the radiometer on the B-side of the tube showed a decrease of pressure when its stopcock was open, so that it was put in communication with the rest of the exhausted system. In no case was there any considerable change of deflection noticed in opening the cock of the radiometer on the A-side of the tube.

When the gaseous pressure in the tube is very much higher than that at which the radiometers can be used to advantage to measure differences of pressure, if a discharge be sent through the tube by means of the above described uni-directional potential-difference, a discharge stream is seen to proceed from the cathode and continue on its course to within a short distance of the opening in the funnel-shaped diaphragm. Here the discharge stream seems to end in a bright band, and from this point on, in the region (B), striæ are seen to succeed one another, as in the stratification phenomenon. The tube in this state transmits discharge through the region (A) by the discharge stream, and through the region (B) by the stratification process. As discharge stream and stratification phenomena are characteristic of different gaseous pressures, this last experiment is in agreement with the experiments described in the preceding paragraph.

Not being provided with a McLeod gauge, or other reliable means of measuring low gaseous pressures, it is impossible to state with accuracy the absolute value of the change of pressure observed by means of the radiometers in the previous experiments. However, the pressure at which the radiometers gave their maximum deflection could not have been far from $50 . 10^{-6}$ Ats., and the pressure at which the first set of the above experiments was made could not have been far from $10 . 10^{-6}$ Ats. The spot of light from the radiometer connected with the B-side of the tube at the above pressure, fell at 80 or 90^{cm} from zero. It seems probable, therefore, that the change of pressure observed amounted to more than 10 per cent of the uniform pressure of the tube.

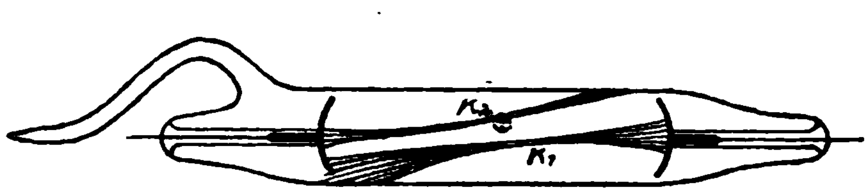
The above experiments would seem to be in good agreement with the considerations in § 3 on the pressure resulting from the motion of a gaseous medium. So that in the above experiments, region (B), into which a discharge stream passes,

being uniformly at a higher pressure (or molecular density) than region (A), from which the discharge stream comes (on account of the law of the conservation of matter), one would apparently be making no mistake in concluding that the discharge stream must convey gaseous matter from region (A) to region (B).

§ 5. In the foregoing considerations and experiments on discharge streams, attention has been almost wholly directed to the discharge stream from the cathode. But if discharge streams are streams of gaseous matter (unless there be a continuous accumulation and rarefaction of the gaseous medium as long as the discharge stream flows), then, according to the law of the conservation of matter, there must be found to be secondary streams, which serve as return streams in the circulation of the gaseous medium. These secondary streams have, in reality, been found to exist.

It is a fact generally observed, in tubes intended for the generation of Röntgen rays, that the glass walls of the tube in front of the electrode struck by the discharge stream from the cathode, fluoresce vigorously. This fluorescence of the walls of the tube is sharply limited (in case of a plane electrode) by the line of intersection of the plane of the electrode with the walls of the tube. If we make the electrode cylindrical in form, the fluorescence of the glass walls is no longer of uniform brilliancy, but appears as a bright line or band on those portions of the tube lying in the direction of the center of curvature of the cylindrical electrode. If, instead of making the electrode cylindrical, we make it of spherical form, the fluorescence of the glass walls no longer shows as a line or band, but as a bright, sharply defined circular or elliptical spot of light, according to the angle of inclination of the axis of the spherical electrode to the glass wall where the fluorescent spot occurs.

5.



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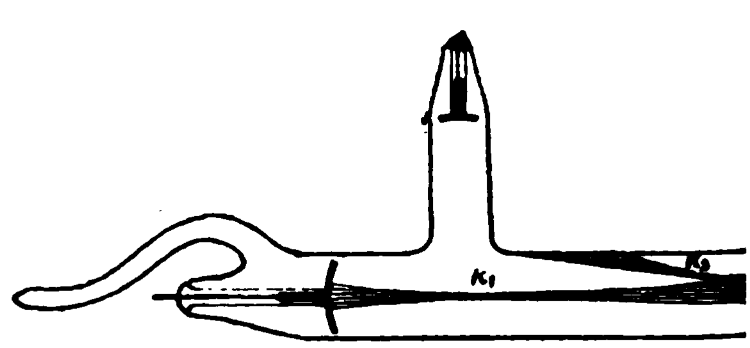

Of the numerous tubes that have been made for the purpose of studying these secondary discharge streams only two will be described at this point. Fig. 5 represents a simple cylindrical tube, provided with two precisely similar spherical aluminum electrodes, of $2{\cdot}5^{cm}$ radius of curvature and $2{\cdot}7^{cm}$ in diameter.

The internal diameter of the tube is $3{\cdot}5^{cm}$ and the two spherical electrodes are $7{\cdot}5^{cm}$ apart.

At comparatively high pressures, and with the ordinary contact maker in the primary, two discharge streams can be distinguished, of almost equal intensity. But if contact be made and broken very slowly, it is seen that these two streams are not simultaneous phenomena, one being produced by the potential-difference at make, and the other at break of the primary circuit. By decreasing the pressure in the tube continuously, one of these streams is seen gradually to grow smaller, and finally entirely to vanish.

On further decreasing the pressure, until the discharge stream from the cathode covers but a small portion of the total area of the cathode a secondary stream from the anode is found to exist, whether we allow the coil to work continuously, or examine the discharge at each make and break of the primary. At make, no discharge stream is seen from either electrode, but at break, the two streams (one from the cathode, the other from the anode) can easily be separated by a magnet, as shown in fig. 5. In some of the early tubes made for the study of these secondary streams, the spherical anode was turned through a small angle, so that the discharge stream from it ordinarily fell on the glass wall of the tube. In this way the two discharge streams can easily be seen, without it being necessary to separate them by a magnet. These experiments have also been performed with the rectified alternating potential-difference, described in § 4; the same evidence of secondary streams as just noted has, in every case, been observed. This experiment will be further discussed in part II of the present paper.

Fig. 6 illustrates a tube that shows these secondary discharge streams under conditions somewhat different from those in the tube just described. The tube has two spherical aluminum electrodes each of $2{\cdot}5^{cm}$ radius of curvature; the electrode in the main tube being 2^{cm}, that in the branch tube $1{\cdot}7^{cm}$ in diameter. The diameter of the main tube is $2{\cdot}5^{cm}$, that of the branch tube at right angles, $1{\cdot}8^{cm}$. The distance between the electrode in the main tube and the opposite glass wall is about 14^{cm}.

At a pressure considerably lower than that at which a discharge stream is sent through the tube on the make of the primary, there is seen to spring from the spherical formed end of the glass tube lying opposite the cathode, a secondary stream, (k_2) in fig. 6. This secondary stream could be deflected by a magnet, caused fluorescence of the glass-walls where it struck, and in all other respects acted as a discharge stream would have acted, coming from a cathode located at the end of the glass tube.

The above described experiments would seem to demonstrate the reality of the secondary discharge streams indicated by the kinetic theory. The experiments also show that these secondary streams do not take definite form until the pressure of the gas (compared with atmospheric pressure) is very low. This, according to the kinetic theory, is what ought to be found.

To examine the kinetic theory, as developed to explain the conduction of heat through gases, for the purpose of determining whether or not this theory can be employed to render an account of the form and action of discharge streams, it will be necessary to call attention to the heat-flow lines from a hot body immersed in a cool gas. Consider a spherical cup at a uniform temperature, higher than that of the surrounding gas, and at great distance from any other solid body. Heat will flow from the spherical body to the surrounding gas along lines at

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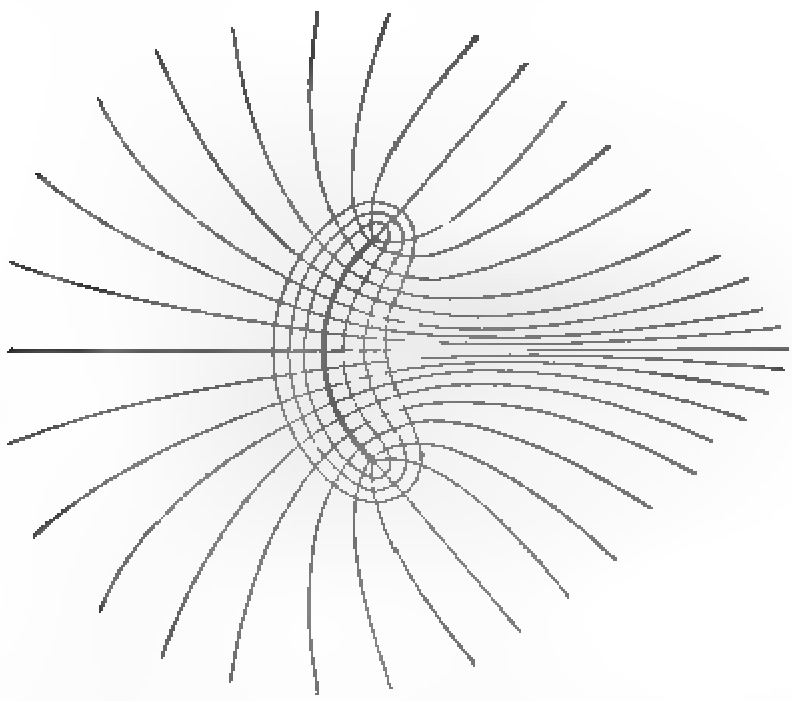
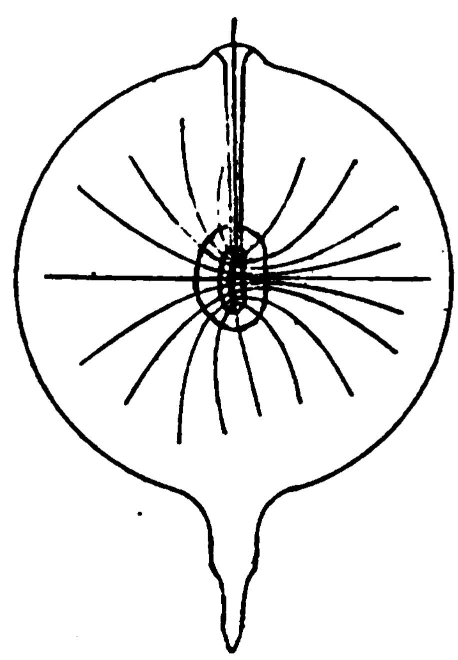


every point normal to surfaces of equal temperature. Thus these heat-flow lines will spring from all points on the spherical surface, normal to the surface at the point of departure. Calling ds an element of the surface of the spherical body, n a normal to the element at its central points, and θ the temperature, then the quantity of heat conducted from this element in unit time, is $k\frac{d\theta}{dn}$; where k is a constant, depending on the nature and state of the gas. If we now define n as the normal to any isothermal surface surrounding the spherical cup, and so choose ds that $k\frac{d\theta}{dn}ds = 1$, we can divide the whole space

surrounding the heated body into unit heat-flow tubes. The central line or axis of each of these tubes, defined as above, may be taken as unit heat-flow lines. These heat-flow lines from a spherical cup, drawn as just indicated, are shown in fig. 7.

The appearance of these heat-flow lines at once reminds us of the form of a discharge stream from a spherical cathode, even in a narrow tube. In order to compare the form of a discharge stream from a spherical electrode, with the heat-flow lines from such a body, conditions, similar to those under which the flow lines illustrated in fig. 7 are supposed to exist, must be chosen. For this purpose, the large bulb illustrated in fig. 8 was constructed. This bulb is, as nearly as may be, a sphere of about 15^{cm} diameter. At the center of the spherical bulb is placed a spherical aluminum electrode of $2{\cdot}5^{cm}$ radius of curvature, and $1{\cdot}85^{cm}$ in diameter. The electrode is connected by a platinum wire to the outside of the bulb.

8.



After exhausting the bulb to a comparatively low pressure, the spherical electrode is connected to one terminal of a spark gap in the secondary circuit of an induction coil. The whole surface of the electrode appears to take part in the action of discharge, and, at pressures not too low, no very well-defined stream can be distinguished. The appearance of the blue discharge is roughly sketched about the electrode in fig. 8. While those portions of the discharge, from the concave side of the electrode in the direction of the axis of the electrode, appear more dense, yet there is no indication of a "focusing" of the discharge at the center of curvature of the electrode. As the pressure is progressively decreased, the general blue discharge from the convex side of the electrode, as well as from the edges and outside portions of the concave side, becomes fainter in comparison with the discharge from the central portion of the concave side of the electrode. The glass walls facing the convex side of the electrode appear to fluoresce almost uniformly; the fluorescence of the walls facing the concave side, falls off very abruptly from the point of intersection of the axis of the electrode with the walls of the bulb. The fluorescence of the bulb on the concave side, at very low pressure, appears as a bright spot (not very sharply defined), at the intersection of the axis of the electrode with the walls. At

this pressure, the discharge producing visible effect in the gas, is almost wholly confined to the concave surface of the electrode. This discharge stream is seen to be affected by a magnet, causes fluorescence of the glass walls, and electrifies the glass walls where it strikes, precisely as a discharge stream from a cathode, in a "conduction tube"; and this, whether the electrode be connected to one or the other side of the spark gap. The above observations have been repeated, with the uni-directional potential-difference described in an earlier paragraph, with the same results as are here given.

In the case of the heated spherical cup, previously considered, the quantity of heat conducted, in unit time, across any isothermal surface limited by any unit heat flow tube, is, by the kinetic theory, $\frac{1}{2}Nmv^2$; N being the number of molecules crossing the surface in one second, in the direction in which heat flows, in excess of the number crossing the surface in the opposite direction, v the mean velocity, and m the mass of the molecules. But $Nm \propto \rho$, the gas density; and $\frac{1}{3}\rho v^2 = p$, the pressure of the gas. So that the heat-flow lines, shown in fig. 7, may be taken to represent the normal component of the pressure brought into existence in the gaseous medium by the operations of heat conduction. Plainly a family of surfaces, over each of which the gaseous pressure has a constant value, can be described about the heated body. These surfaces cut the pressure or heat-flow lines orthogonally, and appear, in a meridian section, as lines everywhere normal to the heat-flow or pressure lines. A few of these lines are shown in fig. 7. The form of these surfaces is practically identical with that of the "dark space," as it recedes from the cathode when the pressure of the gas is reduced.

From the description of the method of drawing the heat-flow or pressure lines, shown in fig. 7, it will be clear that the space rate of variation of pressure outwards, from the heated surface, is a direct function of the angular divergence of the heat-flow lines. Accordingly, as Professor Reynolds* has pointed out, the reaction of the gaseous medium on the convex side of a heated spherical cup ought to be greater than on the concave side. Two such cups ought to rotate, with their concave sides forward when properly pivoted in a rarefied gas, and brought to a higher temperature than the surrounding gas. This they are observed to do in Crookes' cup radiometer.

It was thought worth while to determine whether or not similar reactions could be observed, when the spherical cups instead of being heated, were brought to a high electrical po-

* Cf. note, p. 26.

tential. In order to carry out this experiment, the bulb shown in figs. 9 and 10 was constructed. A spherical bulb, $10{\cdot}8^{cm}$ in diameter, has pivoted on a needle point at its center, a system of four very light spherical aluminum cups, held by four arms going out from a steel pivot, as is shown in fig. 9. These

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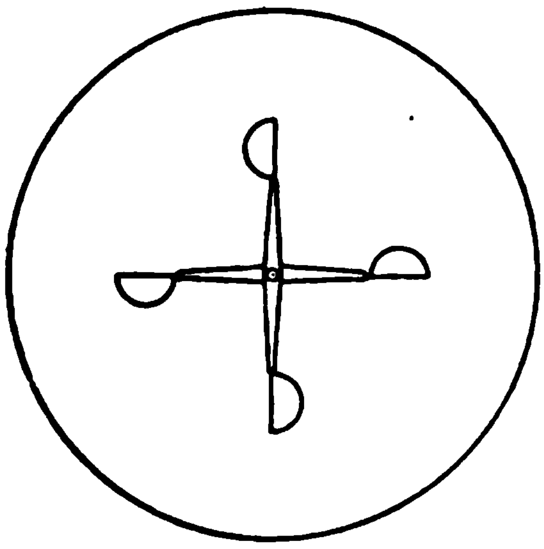

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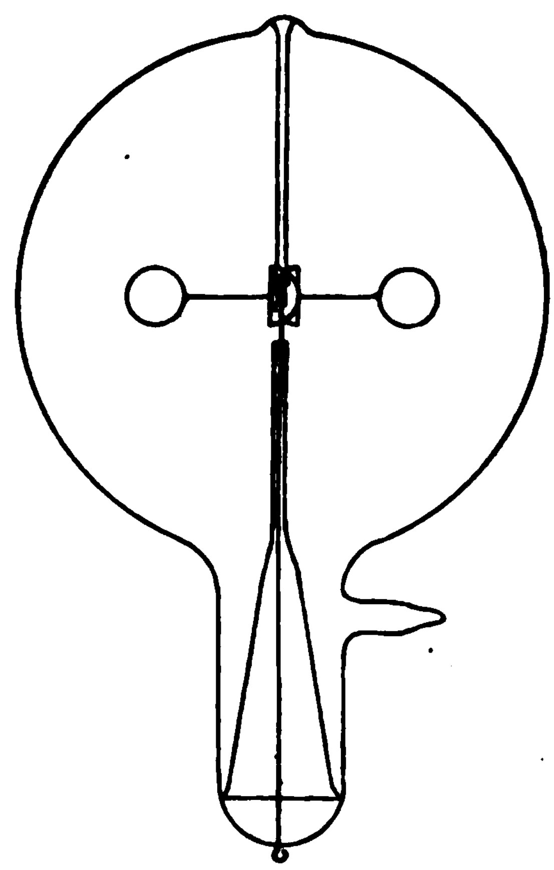

cups are nearly hemi-spherical and are about ${\cdot}5^{cm}$ radius of curvature. The needle point is connected by a platinum wire to the outside of the tube.

When the bulb is thoroughly exhausted by means of a Sprengel pump, the movable system is put in connection with one terminal of the two-part commutator for rectifying the alternating potential-difference of the secondary of the induction coil as described in an earlier section. The cups are seen to rotate, concave side forward. On disconnecting the electrical source, and grasping the bulb in the hands, the cups immediately begin to rotate in the opposite direction and continue to rotate for a short time before coming to rest. The electrification of the walls is very troublesome, but when they are carefully discharged after each operation, the above direction of rotation, upon connecting the movable system with a source of high potential, has been observed, whether the potential of the source be positive or negative in sign.

§ 7. On considering the heat-flow lines from the surface of a hot body immersed in a cool gas, it is clear that the shape of the lines of flow will be affected by the distribution of temperature on opposing or neighboring surfaces. Thus, in fig. 7, if the spherical cup be placed in a closely fitting cylinder, whose walls in the vicinity of the cup, are at a temperature but slightly different from that of the spherical cup, the

distribution of the flow lines will be very much modified. Although the actual determination of the lines of flow would be a somewhat complicated problem, yet it is quite plain that the lines of flow in the region of the edges of the spherical cup would almost wholly vanish, and that the lines from the central portion would appear more crowded together. If beside the cylinder surrounding the spherical cup and heated near the cup, there be a region of very low temperature opposite the concave side of the cup, the lines of flow from the central portion of the cup will be still more condensed. It is also clear that if the gaseous medium in the vicinity of the spherical cup, move in streams from the walls of the surrounding cylindrical surface towards the spherical cup, with very considerable velocity, this motion of translation of the medium will also affect the form of the heat-flow lines from the spherical surface. When this velocity of the medium becomes equal to the velocity of the molecules transmitting heat along the flow lines, then those flow lines where this equality occurs will vanish.

The above considerations relating to the modification of heat-flow lines for a hot body immersed in a cool gas, plainly suggest causes for the remarkable diminution of size and change of form of a discharge stream from the cathode in an ordinary discharge tube, as the pressure of the gas is reduced.

The considerations, and the experiments described in § 5 made it appear that a discharge stream from a cathode is but one part of the cycle performed by the gaseous medium in the operation of transmitting electrical discharge by discharge streams. The energy transmitted by these streams, being dependent on the number and velocity of the molecules forming the streams, it is clear that, as the pressure or molecular density of the gas is reduced, the velocity of translation of the molecules throughout their cyclical course, must increase, in order to transmit the same energy. It thus appears that the velocity of flow of the gaseous medium in the return stream to the cathode, increases as the molecular density of the gas decreases. It was also shown in § 5, that secondary discharge streams can spring from regions electrified by discharge streams from the cathode; and one ought to expect these secondary streams to spring from surfaces electrified in any other way. That the walls of a discharge tube near the cathode are electrified there can be no doubt, for not infrequently the glass walls of the tube break down at this point under the electrical stresses, when the pressure of the gas is very low. It ought thus to be found (due to the electrified walls near the cathode acting as sources of secondary discharge streams), that the stream from the cathode dimin-

ishes in cross-sectional area much more rapidly with pressure, in tubes whose walls lie very near the cathode, than in those whose walls are far removed from the cathode. It ought also to be found that the form of the discharge stream from the cathode is modified by the form of the glass walls near the cathode.

The return stream from the walls of the tube to the cathode, indicated in the foregoing paragraphs, can be observed, during the process of exhaustion, in almost any tube. When the pressure of the gas is such that the discharge stream from the cathode no longer covers the whole area of the electrode, there can clearly be seen a convergent band, or collar of light, beginning near the walls of the tube in the vicinity of the cathode and extending to the base of the discharge stream. The general appearance of this return stream to the cathode is shown in fig. 11 for a spherical electrode. For clearness only

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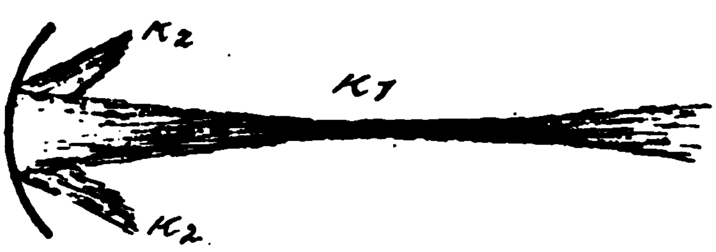
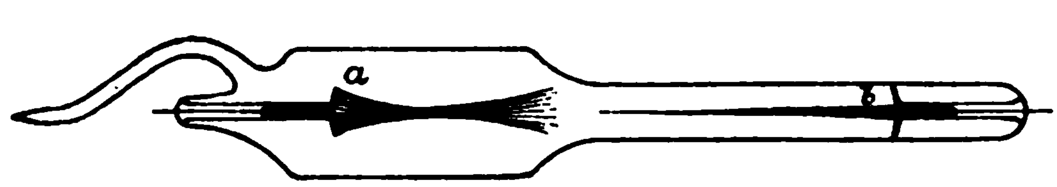


the meridian section of the streams is shown. As the pressure in the tube is decreased, the return stream appears to spring from points on the walls more remote from the cathode; the pink light, by which the return stream is distinguished, becomes fainter, and long before the disappearance of the discharge streams from the cathode, all visible evidence of this return stream has vanished.

For the purpose of illustrating the variation of the action of the walls of a tube with their distance from the cathode, in decreasing the cross-sectional area of the discharge stream from the cathode, the tube illustrated in fig. 12 was constructed.

12.



As will be seen from the figure, it is formed of two cylindrical glass tubes of very different diameters. The large tube is about $4{\cdot}6^{cm}$, and the smaller $1{\cdot}85^{cm}$ in diameter. The two spherical aluminum electrodes are each $1{\cdot}8^{cm}$ diameter, and $2{\cdot}5^{cm}$ radius of curvature. The distance between these electrodes is about 20^{cm}. When the pressure in the tube is not

very low, and (*a*) is the cathode, the discharge stream from (*a*) covers the whole surface of the electrode. The "dark space" still appears around the electrode at about 3^{cm} from it on the concave side. On making (*b*) the cathode, a sharp, very well defined stream is seen to spring from it, and there is no appearance of the "dark space" about the electrode. At this pressure, the area of the electrode (*b*), covered by the discharge stream, is only a small fraction of the total area of the electrode. The walls of the tube being cylindrical, the stream is of circular cross-section, and springs from the portion of the electrode lying immediately around the point of intersection of the axis of the tube with the electrode. As the pressure in the tube is gradually decreased, the area of the electrode covered by the discharge stream from it becomes less and less, until the stream totally disappears. At this pressure, upon making (*a*) negative, the discharge stream from it still covers a considerable portion of the electrode. At very low pressure, discharge can be sent through the tube by making (*a*) the cathode, but cannot be made to pass, with the same potential-difference, when (*b*) is made the cathode. This experiment was repeated by means of a tube identical with that shown in fig. 12, excepting, in place of electrode (*a*), is substituted one whose diameter is just equal to the internal diameter of the large tube, and whose radius of curvature is $3{\cdot}75^{cm}$. The dis-

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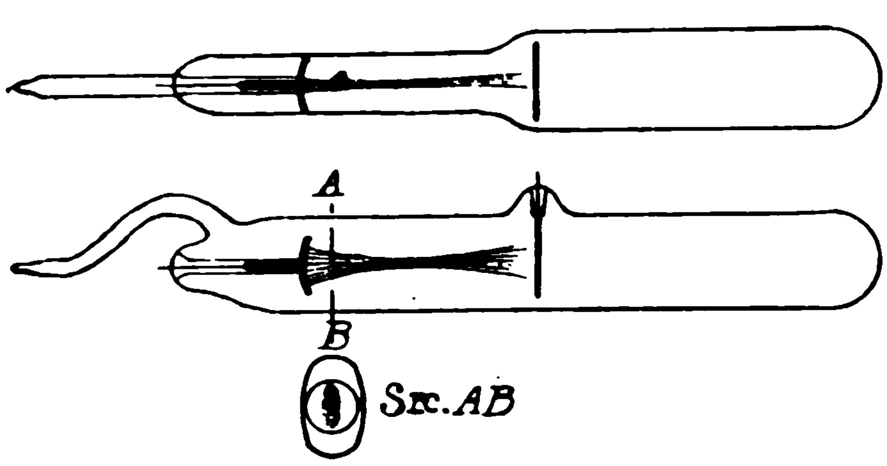

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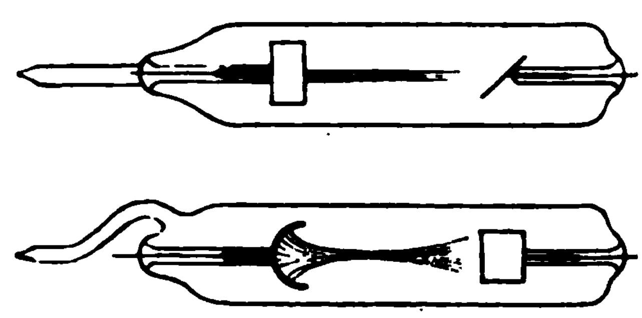

chargestream from the large electrode when it is negative is much more clearly marked than the discharge stream from cathode (*a*) in the tube shown in fig. 12. This is due to the fact that in the last tube all disturbance arising from discharge from the convex side of the electrode is avoided. The same description of the inequality of cross-section, and final vanishing, at extremely low pressure, of the discharge streams from the two electrodes, when first one and then the other is made cathode, as given for the tube shown in fig. 12, applies to the discharge streams from the two electrodes in this tube.

To illustrate the effect of unsymmetrical walls upon the form of cross-section of the discharge stream from the

cathode, the tube shown in fig. 13 was made. It consists of a cylindrical tube $3{\cdot}5^{cm}$ internal diameter, and 25^{cm} long. The walls of the tube for about 8^{cm} in front of the cathode are flattened, so as to be elliptical in form. The cathode is a spherical aluminum electrode $2{\cdot}2^{cm}$ diameter, and $2{\cdot}5^{cm}$ radius of curvature. The anode is a plane platinum disk, placed at right angles to the axis of the tube, and 9^{cm} from the cathode.

The form of the discharge stream from the cathode is shown in the figure. When viewed from the direction of the longer axis of the elliptically-shaped walls, the discharge stream appears as a narrow ribbon, the edges being almost parallel; from a position in the direction of the shorter axis of the elliptically-shaped walls, the stream appears to cover the cathode almost to its edges. From the surface of the cathode the stream converges to a region of minimum thickness, and then diverges until it strikes the anode.

The modification of form of discharge streams, resulting from the unequal velocity of the return streams from the glass walls of the tube, may be further illustrated by the tube shown in fig. 14. This is a cylindrical tube $3{\cdot}7^{cm}$ internal diameter, and 16^{cm} long. The aluminum cathode is cylindrical in form, the radius of curvature being $1{\cdot}2^{cm}$. The dimensions of the electrode are: length parallel to the axis of the cylindrical surface, $2{\cdot}3^{cm}$; across the concave opening, $2{\cdot}4^{cm}$. The anode is a plane platinum plate set at an angle to the axis of the tube.

The return stream from the walls of the tube (traveling in straight lines) must leave the walls at a greater distance from the cathode, in order to reach the central portion of the cylindrical surface, by coming over the sides, than by entering the cathode from the ends. The electrification of the walls of the tube falling off very rapidly from the cathode, the velocity of those parts of the return stream which spring from points on the walls of the tube near the cathode, must be very different from the velocity of those parts coming from points remote from the cathode. The cross-section of the discharge stream from a cylindrical cathode ought, then, to be found to diminish more rapidly (with decreasing molecular density), parallel to the axis of the cylinder, than along the arc of the curved surface.

At its first appearance the discharge stream from the cylindrical electrode seems to spring from the whole concave surface; but as the pressure in the tube is decreased, the stream very soon grows narrow, as viewed from the side of the cathode. The stream also grows smaller along an arc of the curved surface; but its rate of decrease with pressure along the arc is at all times less than in a direction parallel to the axis. As the stream vanishes, it still covers a considerable length of the arc, while its dimension parallel to the axis is a mere line.

The importance of the return stream from the walls of a tube in determining, not only the form and cross-section of the discharge stream, but also the region of the cathode from which the discharge stream springs, is illustrated by the tube shown in fig. 15. The tube is a simple glass cylinder, about

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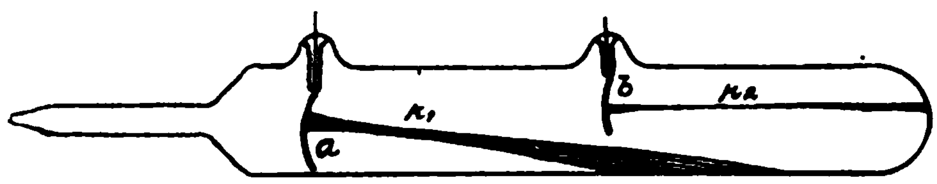


24^{cm} long and $3{\cdot}5^{cm}$ in diameter. It is provided with two spherical aluminum electrodes, each of $2{\cdot}5^{cm}$ radius of curvature. The electrode (*a*) is $2{\cdot}7^{cm}$ in diameter, while (*b*) is $1{\cdot}6^{cm}$ in diameter. The electrode (*a*) is set eccentrically in the tube, so that the edge opposite the point of support is nearly in contact with the inner surface of the glass wall of the tube. The electrode (*b*) is also set eccentrically, but in the opposite direction.

When the pressure in the tube is low, and (*a*) is made cathode, a small, well defined, discharge stream is seen to spring, not from the center of the electrode, but from the point of intersection of the axis of the tube and the electrode. The stream, springing from the electrode normally to the surface, makes an angle with the axis of the tube. As the walls are cylindrical, the cross section of the discharge stream is circular.

Finally, it may be mentioned that it has been found that the form of the discharge stream from a plane, convex, concave, or ring cathode, at a pressure just higher than that at which the stream vanishes, appears to an observer to be almost independent of the form of the electrode.

Princeton University, Princeton, N. J.

ART. III.—*The Crystalline Symmetry of Torbernite;* by T. L. WALKER.

[By permission of the Director of the Geological Survey of India.]

THE minerals of the Uranite group have the general formula $R(UO_2)_2M_2O_8 . 8H_2O$. where R may be Cu, Ca or Ba and M either P or As. Two of the minerals are considered to be tetragonal, and the other three rhombic, though their angles and axial relations are almost identical with those of the two tetragonal minerals.

Torbernite — $Cu(UO_2)_2P_2O_8+8H_2O$ tetragonal — $c = 2{\cdot}9361$
Zeunerite — $Cu(UO_2)_2As_2O_8+8H_2O$ " — $c = 2{\cdot}9125$

Autunite —$Ca(UO_2)_2P_2O_8+8H_2O$ rhombic $\breve{a} : \bar{b} : \dot{c} = {\cdot}9875 : 1 : 2{\cdot}8517$

This similarity in chemical constitution combined with the close morphological affinity indicated by the axial relationships, leads one to ask whether the whole group may not be isomorphous and belong to the same crystal system. It will be generally admitted that the crystals of these minerals are seldom suitable for accurate goniometric determinations, as is evidenced by the varying results obtained by different well known observers. The measurements quoted by Dana* for torbernite vary in many cases from one to two degrees, very considerable differences when we consider its close resemblance to autunite, which is plainly not of a higher grade of symmetry than rhombic.

Brezina† examined autunite from Johanngeorgenstadt and concluded that it was monoclinic and only pseudo-rhombic. He assigned the axial relationships

$$\grave{a} : \bar{b} : \dot{c} = 0{\cdot}3463 : 1 : 0{\cdot}3525$$

We may express the same proportions by the following figures,

$$\grave{a} : \bar{b} : \acute{c} = 0{\cdot}9886 : 2{\cdot}8379 : 1$$

This brings out clearly the close relationship between the monoclinic form calculated by Brezina for autunite and the commonly accepted rhombic proportions

$$\grave{a} : \bar{b} : \acute{c} = 0{\cdot}9875 : 1 : 2{\cdot}8517$$

It is thus seen that Brezina orients the crystals so that the ver-

* System of Mineralogy, 6th ed., p. 856.
† Zeitschr. f. Kryst., iii, p. 273.

tical axis becomes the orthodiagonal and the perfect cleavage basal according to the rhombic orientation becomes clino-pinacoidal.

I give below some of the reasons which lead me to conclude that torbernite as well as autunite is monoclinic and that the uranite minerals form an isomorphous group.

1. *Isomorphism of torbernite and autunite as described by William Phillips in 1815.*—One of the first writers on this mineral group was William Phillips, who read a paper before the Geological Society of London in 1815 "On the oxyd of Uranium." His paper is accompanied by three fine plates, which make it clear that in his day autunite and torbernite had not been separated. His specimens were principally from Tol Carn and Tin Croft in Cornwall. Speaking of the color of the crystals he says: "On other specimens the crystals are transparent and of a greenish hue, whence they pass through almost every shade into deep grass green; while in others the center of the crystal is yellow and the edges only are green."* He is clearly describing crystals whose centers are composed of the yellowish mineral autunite while the green border mineral is one of the copper uranite, most probably torbernite. At that time Mitscherlich had not yet stated his Law of Isomorphism, neither does it appear that Phillips knew the essential chemical difference between the yellow and green crystals. His descriptions are of great value, for in those days excellent specimens were to be had in abundance. He says: "There are in my possession 55 specimens of oxyd of uranium from the various mines in Cornwall above cited and upwards of 200 detached portions each having one or more well defined crystals."† At present very few museums possess more than a dozen specimens all told.

If autunite and torbernite be isomorphous then what Brezina has established for autunite applies also to torbernite and it becomes probable that both minerals are monoclinic.

2. *Cleavages of torbernite.*—All the minerals of the Uranite Group have one very perfect cleavage which is parallel to the basal pinacoid according to the commonly accepted orientation of the crystals. In addition to this, basal cleavage fragments show two other fairly perfect cleavages which appear to intersect at right angles—in torbernite said to be parallel to the prism of the second order (100) and in autunite parallel to the macro- and brachy-pinacoids (100) and (010). In the latter mineral these two cleavage directions are plainly unequally developed, which is to be expected in pinacoidal cleavages of a rhombic crystal. In torbernite however the two cleavage

* Trans. Geol. Soc., vol. iii, p. 114.
† Loc. cit., p. 118.

directions are equivalent and the cleavages should be equally perfect if the mineral be tetragonal. This however is not the case. If we regard torbernite as rhombic or monoclinic this difference of cleavage would be quite regular.

3. *Evidence from Etching Figures.*—Thin cleavage plates parallel to (001) were treated for fifteen seconds with hot 5 per cent nitric acid. The operation is best performed in a porcelain dish using about 5^{cc} of the dilute acid, the action being terminated by adding 250^{cc} of cold water when the desired corrosion period is ended. After drying, the cleavage fragments were examined under the microscope and showed monosymmetric etching figures in abundance (fig. 1). These figures are symmetrical about one plane only and that plane is parallel to the better of the cleavages observed in basal cleavage fragments. This indicates that torbernite is monoclinic and that the very perfect so-called basal cleavage and the less perfect of the other two cleavages lie in the zone of the ortho-diagonal, while the third (second best) cleavage is clino-pinacoidal. It must be remarked that this orientation does not agree with that adopted by Brezina for autunite, for he finds the best or basal cleavage so-called to be clino-pinacoidal while the etching figures indicate that in the case of torbernite this cleavage lies in the orthodiagonal zone.

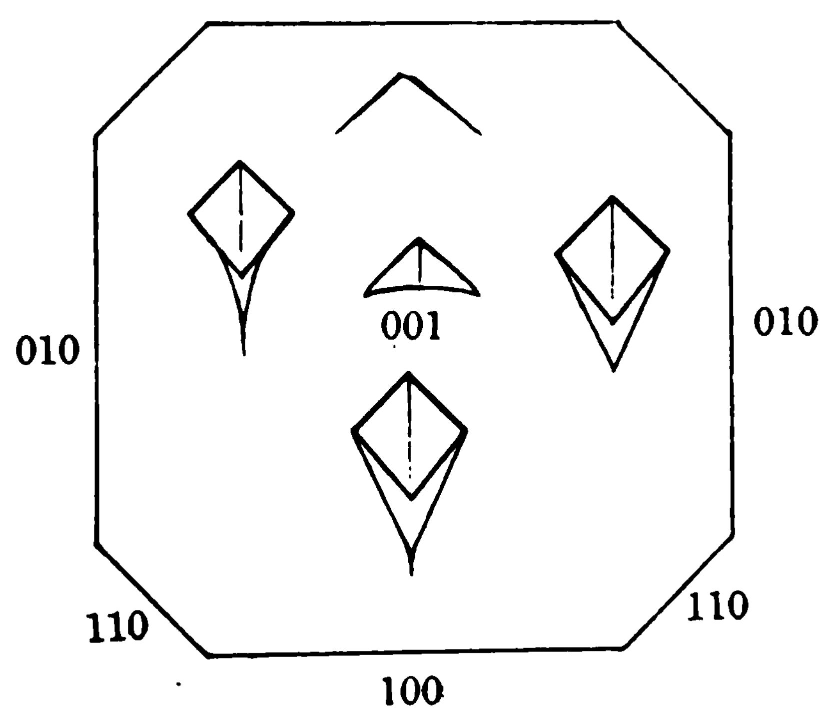


FIG. 1. Basal section of torbernite showing etching figures produced by 5 per cent hot nitric acid by 15 seconds corrosion. Figures much enlarged.

The progress of corrosion tends to obliterate the monoclinic character of the etching figures, though they never lose the habit completely. It may be stated as a general rule that corrosion figures become less plain with the progress of the reaction after a certain stage has been reached, and the chief difficulty in preparing etching figures for microscopic examination is to interrupt the reaction just when that stage of best definition is reached.

4. *Optical properties.*—Thin basal cleavage plates when viewed under the microscope between crossed nicols in convergent polarized light give a biaxial interference figure with a very small optical angle—much like those observed in many biotites. Though nearly uniaxial the biaxial character is so constant in all parts of the thin plates that by revolving till the cross is perfect it is regularly seen that the directions of the two cleavage systems and the cross hairs agree. Though the optical angle is quite small the biaxial nature of torbernite is plain—much more so than in the majority of biotites. But even if at times the interference figures were practically uniaxial, that would not be sufficient ground for retaining torbernite as a tetragonal mineral any more than the very small optical angle for biotite would justify one in maintaining that biotite is hexagonal. The case of biotite, pseudo-hexagonal in form and with very small optical angles, at times practically uniaxial and torbernite, pseudo-tetragonal in form with a very small optical angle, are quite analogous. The minerals also resemble one another in offering only poor crystals for goniometric determinations and in being plainly monoclinic when examined by means of corrosion figures.

Indian Museum, Calcutta.

ART. IV.—*Further Separations of Aluminum by Hydrochloric Acid;* by FRANKE STUART HAVENS.

[Contributions from Kent Chemical Laboratory of Yale University—LXXI.]

IN former papers* from this laboratory methods have been described for the separation of aluminum from ferric iron, and from beryllium, based on the insolubility of the hydrous aluminum chloride in a mixture of equal parts of aqueous hydrochloric acid and ether saturated with hydrochloric acid gas, the ferric and beryllium chlorides being exceedingly soluble in this mixture.

It was the purpose of the investigations herein described to discover how far this process could be extended, with certain modifications, to cover the separation of aluminum from such other metals as might occur with it, either in artificially prepared alloys or in naturally-occurring compounds.

The aluminum used in all the following experiments was in the form of a solution of the chloride. This chloride was purified, as previously described,† from iron by precipitation with hydrochloric acid, and from the alkalies by precipitation as the hydroxide and continued washing with water until the washings gave no test with silver nitrate. The hydroxide thus obtained was dissolved in hot hydrochloric acid to get it into the form of the chloride. The chloride solution was standardized by precipitating weighed portions with ammonia and weighing as the oxide.

Separation of Aluminum from Zinc.

A solution of pure zinc chloride made by dissolving metallic zinc, free from impurities, in hydrochloric acid, is not precipitated when treated with an equal volume of ether and saturated with hydrochloric acid gas.

To prepare a definite zinc salt free from traces of the alkalies which would be precipitated with the aluminum by strong hydrochloric acid, pure metallic zinc was dissolved in hydrochloric acid, the dilute solution precipitated with ammonium carbonate, and the resulting carbonate ignited to a constant weight as zinc oxide. This oxide dissolved in hydrochloric acid gave a pure chloride.

The aluminum in all these experiments was determined in the following manner:—Portions of the prepared solution of aluminum chloride were weighed in a small beaker, weighed portions of zinc oxide added and sufficient aqueous hydrochloric

* Gooch and Havens: this Journal, vol. ii, p. 416.
Havens: this Journal, vol. iv, p. 111.
† Loc. cit.

acid to dissolve it. The beaker was then cooled by immersion in an inverted bell-jar supplied with running water by means of inlet and outlet tubes, and a current of gaseous hydrochloric acid (generated by the gradual addition of sulphuric acid to a mixture of hydrochloric acid and salt) passed through the solution in the beaker to complete saturation. Ether was added in volume equal to that of the original solution, and the whole again saturated with hydrochloric acid gas. The crystalline chloride precipitated was caught on asbestos in a filter crucible, washed with a previously prepared solution of equal parts of ether and hydrochloric acid, saturated with hydrochloric acid gas, dried for half an hour at 150°–180° C., covered with a layer of pure mercury oxide, heated gently over a low flame under a ventilating hood, ignited over the blast, and weighed as the oxide. The results show that aluminum can be determined with reasonable accuracy in the presence of a pure zinc salt.

TABLE I.

	Al_2O_3 taken as the chloride. grm.	Al_2O_3 found. grm.	Error. grm.	ZnO taken. grm.	ZnO found. grm.	Error. grm.	Error corrected. grm.	Final vol. cm³.
(1)	0·0562	0·0562	0·0000	0·1110	----	----	----	--
(2)	0·0580	0·0577	0·0003−	0·1034	----	----	----	--
(3)	----	----	----	0·1019	0·1016	0·0003−	----	--
(4)	----	----	----	0·1010	0·1007	0·0003−	----	--
(5)	----	----	----	0·1100	0·1095	0·0005−	----	--
(6)	0·0572	0·0572	0·0000	0·1014	0·1027	0·0013+	0·0007−	12
(7)	0·0563	0·0550	0·0013−	0·1026	0·1038	0·0012+	0·0008−	16
(8)	0·0577	0·0576	0·0001−	0·1000	0·1014	0·0014+	0·0006−	16
(9)	0·0559	0·0558	0·0001−	0·1020	0·1035	0·0015+	0·0005−	16
(10)	0·0563	0·0556	0·0007−	0·2024	0·2046	0·0022+	0·0002+	20
(11)	0·1111	0·1107	0·0004−	0·2092	0·2116	0·0024+	0·0004+	20

The zinc can be determined, after the evaporation of the strong acid filtrate, by any of the well known methods. It was found, however, that after thorough conversion to the nitrate by repeated evaporation with nitric acid the salt could be ignited directly to the oxide with satisfactory results. This is shown clearly in Table I, exps. (3) to (5). In experiments (3) and (4), zinc oxide was dissolved in nitric acid and the nitrate ignited again to the oxide. In experiment (5), the zinc oxide was first dissolved in hydrochloric acid and the chloride thus obtained was converted to the nitrate by evaporating the solution (5^{cm^3}) with nitric acid (2^{cm^3}), treating the residue with nitric acid (2^{cm^3}) and evaporating to dryness.

In Table I (exps. 6–11) are given the results of experiments in which both the aluminum and zinc were determined,—the former, as described, by precipitating as the hydrous chloride and weighing as the oxide, and the latter by carefully evaporating the strongly acid filtrate (best with a small current of air

playing on the surface of the liquid to avoid spattering due to the too violent evolution of the ether and gaseous acid) and finally converting the chloride through the nitrate into the oxide. It is, of course, absolutely necessary that the treatment with nitric acid shall be thorough, so that no zinc chloride may remain to volatilize when the residue is ignited. On account of the danger to platinum from the aqua regia generated by the action of nitric acid on zinc chloride, the evaporations of the filtrates from the aluminum chloride and the treatment with nitric acid were carried on in porcelain and the residual nitrate was transferred to a small crucible for ignition. In this process the porcelain was evidently attacked somewhat, so that the residual nitrate was slightly contaminated with material from the large porcelain dish. This fact accounts for the high results given in the first column of errors. However, on introducing a correction (0·0020) found by carrying through the process in blank with the quantities of reagents employed in the regular process, the results on zinc, slightly deficient, agree closely with those obtained (exps. 3–5, Table I) where the zinc nitrate was converted directly to the oxide without the previous evaporation in porcelain of a large volume of strongly acid liquid. The errors thus corrected stand in another column of the table.

These results show clearly that aluminum and zinc may be separated from one another by the action of hydrochloric acid gas in aqueous ethereal solution with a reasonable degree of accuracy.

Separation of Aluminum from Copper, Mercury and Bismuth.

The separation of aluminum from copper, mercury and bismuth does not differ materially from the separation of aluminum and zinc. Aluminum chloride is precipitated quantitatively in the presence of pure salts of these elements as shown in experiments of Table II.

TABLE II.

	Al_2O_3 taken as the chloride. grm.	Al_2O_3. fonnd. grm.	Error. grm.	CuO taken. grm.	CuO found. grm.	Error. grm.	$HgCl_2$ taken. grm.	Bi_2O_3 taken. grm.
(1)	0·0576	0·0571	0·0005–	0·0500	....	....	....	....
(2)	0·0561	0·0557	0·0004–	0·0400	....	....	....	....
(3)	0·0570	0·0574	0·0004+	....	....	....	0·1000	....
(4)	0·0548	0·0557	0·0009+	....	....	....	0·1000	
(5)	0·0565	0·0571	0·0006+	....	....	....	....	0·1000
(6)	0·0576	0·0577	0·0001+	....	....	....	....	0·2000
(7)	....	....	....	0·0437	0·0432	0·0005–	....	....
(8)	....	....	....	0·0359	0·0359	0·0000	....	....
(9)	....	....	....	0·0345	0·0340	0·0005–	....	....
(10)	0·0558	0·0545	0·0013–	0·0319	0·0324	0·0005+	....	....
(11)	0·0538	0·0536	0·0002–	0·0343	0·0356	0·0013+	....	....
(12)	0·0566	0·0562	0·0004–	0·0337	0·0349	0·0012+	....	....
(13)	0·0577	0·0575	0·0002–	0·0651	0·0644	0·0007–	....	....

In determining the copper in the acid filtrate it was found advantageous to weigh as the oxide, but to arrive at that condition through the sulphate rather than through the nitrate (which was the transition salt in the case of zinc), as this process can be carried on safely in platinum.

In Table II (exps. 10 to 13) are given results of experiments in which the aluminum was determined as previously described by precipitation as the hydrous chloride and conversion to the oxide, the acid filtrate was evaporated in platinum and the copper determined by treating the residue with a few drops of strong sulphuric acid, heating gently to drive off the excess of sulphuric acid, and then igniting the sulphate to the oxide at a red heat. That the copper sulphate is converted to the oxide by ignition at a red heat over a Bunsen burner is shown in experiments (7) to (9) of Table II.

In conclusion the author wishes to thank Professor Gooch, under whose direction this work has been carried on, for his kind suggestions and advice.

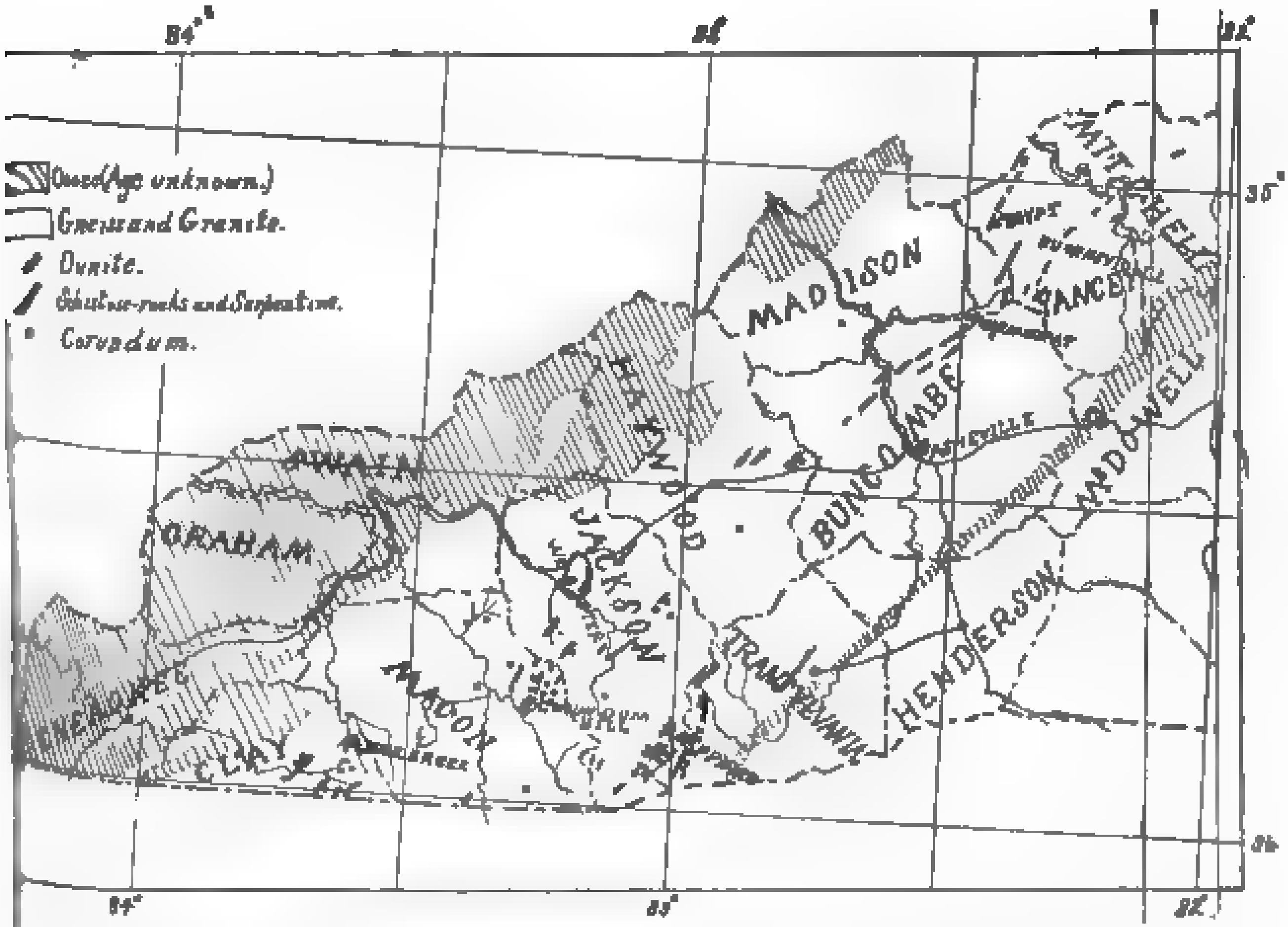
Art. V.—*On the Origin of the Corundum associated with the Peridotites in North Carolina;* by J. H. Pratt.

[Published by permission of the Director of the North Carolina Geological Survey.]

Introduction.—During the past few years there have been numerous investigations upon the character and origin of the peridotite (dunite) rocks of the Appalachian belt, especially those occurring in the southern portion of this belt. In a recent paper, J. V. Lewis* has shown that these peridotites are to be regarded as plutonic igneous rocks.

The author has examined nearly all the known outcrops of these rocks, in this State, during the past two years, in connec-

1.



tion with his work on the corundum deposits. The result of these examinations have led to the same conclusion regarding the origin of the peridotites as that held by Prof. Lewis and others. Corundum is nearly always associated with these rocks; and while several valuable contributions have been written on the occurrence and descriptions of localities, but few investigators have taken up the study of this mineral in

* Elisha Mitchell, Sci. Soc. Jour., Part II, pp. 24 37, 1895.

respect to its origin. That there are several modes of origin of corundum would seem clear from the various ways in which it occurs. Its association with the plutonic and metamorphic rocks, such as granites, gneisses and crystalline schists, is well known, as also its occurrence in basic igneous rocks. The corundum, which is the subject of this paper, is that which is found associated with the peridotites; and the accompanying map, fig. 1, shows the distribution of these and of the corundum in western North Carolina.

In the accompanying pages it is purposed to give the reasons why the corundum should be regarded as having been formed at the same time with the dunite, as having been held in solution by the molten mass of the dunite and having crystallized out among the first minerals as the mass began to cool.

2.

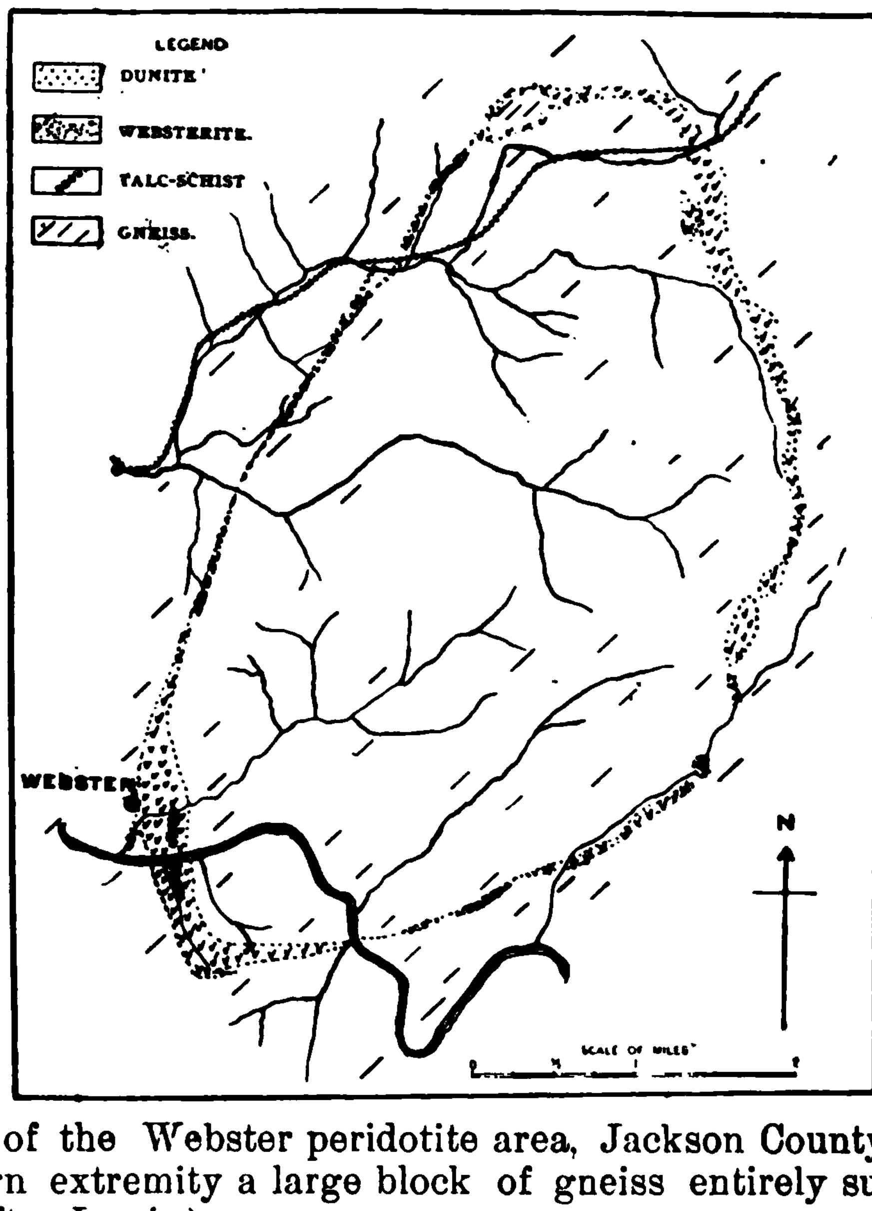


FIG. 2. Map of the Webster peridotite area, Jackson County, N. C., showing near its northern extremity a large block of gneiss entirely surrounded by the peridotites. (After Lewis.)

This theory of the origin of the corundum depends upon the igneous origin of the peridotites and it seems advisable at this point to review the reasons why the peridotites of this region are to be regarded as igneous rocks, and to state new facts bearing on this view. Most of the points brought out by Lewis have been verified by the author from personal observation, and a brief summary of them is given here:

The blunt lenticular form in which we find these peridotites

would be difficult to associate with any origin but that of an intruded igneous mass, which would also account for the apophyses that have been observed shooting off into the enclosing gneiss.

At Webster, Jackson County, as shown in fig. 2, a large block of gneiss is completely enclosed in such a manner by the peridotites, as could be attributed only to the intrusion of these in a molten condition.

The line of separation of the peridotites and the gneisses is always sharp, and there is no transitional zone from the acid gneiss to the basic peridotite. Under the microscope this latter rock shows the granular structure characteristic of plutonic origin, the grains fitting perfectly with each other without cementing material.

The stratified appearance of the olivine at Webster, Jackson County, is readily accounted for by the pronounced evidence of shearing that accompanies it. Dr. Wadsworth* has shown that the evidence given by Dr. Julian† to prove that these peridotites were of sedimentary origin could exist just as well if the rock had an entirely different origin.

At the Buck Creek and adjoining localities, amphibolite dikes cut the peridotites or pass up through the same opening with them in such a manner as to clearly indicate that the peridotites occupy areas of weakness in the gneiss, through which the dikes have found their exit most easily.

Associated with all these peridotites is chromite, which occurs in imbedded masses near the boundary of the lenticular bodies of peridotite and as disseminated particles through its borders. But at one locality, Webster, the grains of chromite appear to be disseminated throughout the mass of the dunite. The constant occurrence of this mineral, so characteristic an accessory component of the igneous peridotites, and the almost entire absence of the carbonates so commonly associated with metamorphic olivine and serpentine rocks, are strong factors in the proof of an igneous origin of these peridotites. All the carbonates that have been observed by the author in connection with the peridotites are unquestionably of a secondary origin. Five or six specimens of aragonite have been observed at Corundum Hill, Macon County, and one at Buck Creek, Clay County, intimately associated with deweylite, an alteration product of the dunite.

W. C. Kerr‡ and C. D. Smith‡, who spent much time in the study of these peridotites rocks in the field, were both of the opinion that they are of igneous origin.

* Science, iii, pp. 486, 487, 1884.
† Nat. Hist. Soc. of Boston, xxii, pp. 141–149, 1852.
‡ Report of N. C. Geol. Survey, vol. i, 1875, appendix p. 91.

Historical.—As was stated above, but little has been published regarding the origin of corundum, although many authors in their papers on the occurrence of corundum and the peridotites mention what they consider might be the probable origin of this mineral.

In 1872, C. U. Shepard* in an extended article on the corundum of North Carolina and Georgia, describes the occurrences of corundum and chrysolite, the associated minerals and what he calls the development of the "Strata" which "exhibit the following order of formations: 1. Chrysolitic rock somewhat mixed with anthophyllite; 2. a layer of micaceous rock; 3. a seam of chalcedony; 4. a stratum of chloritic rock (ripidolite); 5. the same through which the corundum is regularly diffused, sometimes in narrow veins or widening out to several feet." Nowhere in this article does he suggest the probable origin of the corundum.

J. Lawrence Smith† in describing the occurrence of corundum associated with the peridotites of North Carolina and Georgia, speaks of all the localities of corundum that he has observed or examined as exhibiting certain prominent characteristics common to all, but with each locality having its own peculiar characteristics. He says that in all cases, however, the masses of corundum give evidence of having been formed by a process of segregation, which he has described in a memoir‡ on the Asia Minor emery; that by the exercise of homogenous and chemical attractions, the minerals which constitute and are associated with emery were separated out from the calcareous rock before it consolidated.

Genth,§ although not touching directly on the origin of corundum or giving any evidence to sustain his statement, says, "that at the great period when the chromiferous-chrysolite beds were deposited, a large quantity of alumina was separated which formed beds of corundum." This corundum has subsequently been acted upon and altered and changed into various minerals; that the "veins" of chlorite, etc. are alterations of the original mass of corundum and that the corundum might be found in a less altered or wholly unaltered condition when the vein was explored below the action of surface influences. In speaking of the corundum crystals imbedded in the chlorite, Dr. Genth says the crystals "appear to have formed after a great portion of the original corundum has changed into chlorite, as if there had been an excess of alumina ready for combination, which, not finding a supply of

* This Journal, III, iv, pp. 109–114, 175–177, 1872.
† This Journal, III, vi, pp. 180–6, 1873.
‡ This Journal, II, x, p. 354, 1850.
§ Proc. Am. Phil. Soc., xiii, pp. 361–406, 1873, and this Journal, III, vi, pp. 461–462, 1873 (review).

the requisite amount of silicic acid and bases, had again crystallized as corundum."

In an article on corundum and its associated rocks, C. D. Smith* points out the facts that led to his belief in the igneous origin of the peridotites, but does not discuss the same. He calls attention to the occurrence of corundum chiefly in chlorite veins and says "the chlorite seems to have been first crystallized, and then, the alumina of which the corundum is composed was evidently in a state of solution and must have permeated the chlorite either in thermal waters or steam." The only points given to sustain this theory are that plates or scales are sometimes enclosed in the corundum and that corundum has been observed that conforms in its faces and general shapes to the chlorite that is present. The other points bearing on the origin of the corundum that he undoubtedly had in mind he makes no mention of in his article. Dr. Smith also states that he found "chrysolite attached as an enveloping matter to considerable masses of corundum." He makes, however, apparently no further mention of this occurrence in any of his writings.

In a description of the "Jenks Corundum Mine," Dr. R. W. Raymond† calls attention to the occurrence of transparent nodules of corundum in a matrix of the same mineral, and also of the great variation in the appearance of the corundum from the different veins. One of the veins has produced more of the gem material, while it contains but few large masses of the corundum.

Julian, in his paper already cited, considered the corundum in all cases a secondary or alteration product, and explains all the phenomena of alteration in the veins by the introduction of a solution of soda and alumina into the fissures, during the period of alteration and metamorphism, believing at the time that the dunite was of sedimentary origin.

In an article commenting on Julian's‡ theory regarding the origin of the peridotites referred to above, Wadsworth,§ in speaking of the corundum, says that the corundum is looked upon as a secondary mineral, and not as Genth held, the primary material from which many minerals originated.

Chatard‖ made a very careful chemical study of the material collected across the contact between the gneiss and dunite at Corundum Hill. He points out as a result of his chemical analyses, that starting from the gneiss there is a progressive

* Report of N. C. Geol. Survey, vol. i, p. 91, 1875.
† Trans Am. Inst. of Min. Engrs., vol. vii, p. 89, 1879.
‡ Nat. Hist. Soc. Bost., xxii, 141–149, 1882.
§ Science, iii, 1884, p. 486.
‖ U. S. Geol. Survey, Bulletin 42, pp. 45–63.

increase of magnesia in the vein material as the dunite is approached, and that there is an approximate decrease in the percentage of alumina.

From these analyses, the series from the section across the vein are divided into three groups, aluminum silicates, aluminum-magnesium silicates, and magnesium silicates. The middle term of this chemical series is also the middle number of the field series. He regards the corundum as an accessory mineral, frequently not being found at all in the vein, and sometimes but in small amount, and therefore to be considered as the result of a certain balance between the magnesium and aluminum silicates, which have by their union produced the chlorite and vermiculites.

In describing the occurrence of corundum at Chester County, Pa., Mr. J. P. Lesley* says that it seems difficult to imagine its excessive compact hardness as produced in any other way than by heat.

J. V. Lewis'† report on "Corundum and the Basic Magnesian Rock in North Carolina" is mainly a report of field observations and does not take up any discussion of facts bearing on the origin of the corundum; though many points of interest and importance are brought out regarding the alterations of the dunite and of the character of the vein and vein materials and also concerning the alteration of corundum.

The corundum deposits of Georgia are similar, almost identical, with those in North Carolina. F. P. King,‡ in his report on the corundum deposits of Georgia, which is principally devoted to the description of localities, occurrences and varieties of corundum, etc. comes to the conclusion that corundum is an accessory mineral and that its presence is occasioned by an excess of alumina present in the rock masses, "chrysolite, gneiss and hornblende gneiss." This is explained by the alteration of these rocks into magnesium silicates, alkaline salts and ferro-silicates, which in conjunction with carbonic acid of percolating waters would dissolve the combined alumina, and produce on crystallization all the minerals associated with corundum; and when the alumina is in excess this would produce corundum itself.

As has been shown above, a number of theories concerning the origin of the corundum have been advanced. With one exception, however, they are all prior to the numerous and elaborate experiments that have been made by different investigators on the solubility of alumina in a molten basic glass and the separating out of corundum and spinel crystals from

* Penn. Geol. Survey, C4, p. 352, 1883.
† N. C. Geol. Survey, Bulletin No. 11.
‡ Georgia Geol. Survey, Bulletin 2.

this on cooling. They are also prior to Vogt's* very important investigations into the igneous origin of certain ore deposits. All these experiments have aided very materially in solving the numerous problems in relation to the origin of many of the ores; and in the present investigation the facts proved by these experiments have been of exceptional assistance in the compiling of evidence to substantiate the theory proposed.

Evidence bearing on origin of Corundum.—In all the field observations a careful search was made to find the corundum directly in contact with the dunite, and this was observed at one locality. At the Egypt mine, on the western slopes of the Samson mountains, about ten miles west of Burnsville, in Yancey county, several specimens have been found with the corundum crystals entirely surrounded by granular dunite, and showing none of the chloritic minerals usually present with the corundum (fig. 3). Both the dunite and the corundum

3.

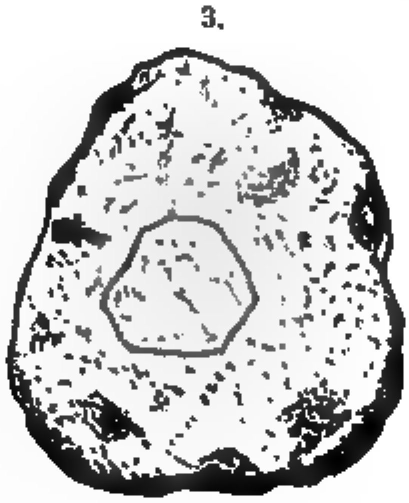


FIG 3.—Corundum crystal in altered dunite. From Egypt, Yancey County. One-half natural size. (Drawn from a photograph.)

have altered somewhat, the corundum having a little muscovite developed on its basal termination, while the dunite is stained a yellowish brown and is rather friable. The specimens that were examined were collected by Mr. U. S. Hays, who was prospecting in the vicinity of the mine, and were loaned to the author by J. V. Lewis,† who has described this occurrence. There was no mining being done when this locality was visited by the author, but miners living in the vicinity, and who have worked in the mine, report the finding of many fragments of corundum in the dunite similar to the one here figured.

Although this is the only locality where the corundum has

* Zeitschr. für Prakt. Geol., Nos. 1, 4 and 7, 1893

† N. C. Geol. Survey, Bulletin No. 11, p. 60.

been found directly in dunite, it has been observed in serpentine, which is the commonest alteration product of dunite. At the Cullakeenee mine, Buck Creek, Clay County, corundum was found that was bordered with serpentine. Some of the specimens observed show the small particles of corundum either entirely or partially surrounded by serpentine and the whole mass of corundum and serpentine surrounded by clinochlore. In another specimen a streak of corundum about an inch wide lies between two zones of serpentine, from a quarter to three quarters of an inch wide, and these in turn are bordered by a talcose and enstatite rock (fig. 4).

4.

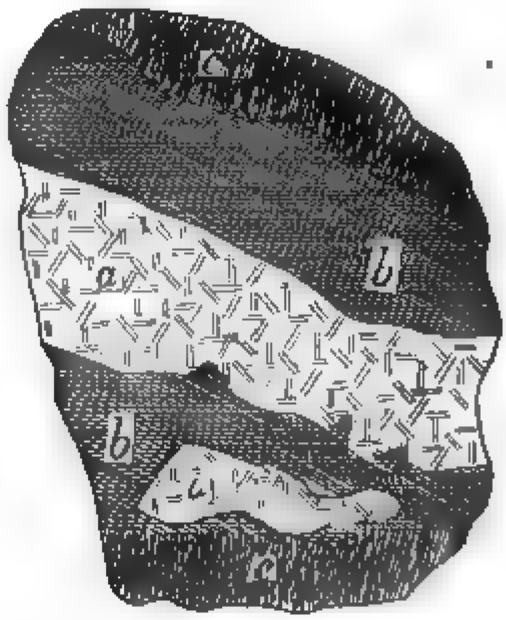


FIG. 4. Drawn from hand specimen. One-half natural size: *a*, corundum with a little margarite developed in a few places near the border of the serpentine *b*. The serpentine blends somewhat with the talcose rock *c*, which on its outer surfaces is composed of enstatite.

Crystallized corundum has been observed, where the crystals, one end of which merge into the massive corundum, project out beyond the mass, and these projecting portions are often partly or entirely surrounded by chlorite; while in other cases separate corundum crystals are imbedded in the chlorite. The best crystals of corundum have been found at Corundum Hill, where they occur in the conditions just mentioned.

Many of the crystals, especially those free from alteration and decomposition, or those only slightly altered, are usually well developed, with smooth even faces and sharp edges.

In a number of the mines, corundum is found in contact with and surrounded by spinel. At the Carter Mine, near Democrat, Buncombe County, the corundum is found in masses of a white and pink color, intergrown with a greenish

black massive spinel. In thin splinters the spinel is of a very handsome emerald-green color. The masses of the corundum and spinel are partially surrounded by a deep green chlorite; which latter has also in places been developed in small greenish scales, between the corundum and spinel; though the contact of the spinel and of the corundum is usually sharp and distinct, showing no sign of alteration. The presence of minute scales of greenish chlorite occur still more rarely in the corundum and spinel near the junction of these minerals with the external mass of the chlorite. All the massive corundum shows the characteristic parting lines; and the spinel shows distinctly the conchoidal fracture.

A massive, coarsely to finely granular spinel is found at the Corundum Hill mine, Macon County, which has disseminated through it small grains and fragments of pink and white corundum. The spinel and corundum are closely associated with chlorite, which is here more generally developed between the corundum and spinel and in the spinel (between the granules) than it was at the Carter mine. The spinel in the mass appears black, but in small splinters it shows a green color.

The corundum is found in the dunite in two different relations, one in the zone of alteration products developed at the contact of the dunite and the gneiss, and the other in a similar zone of alteration products, but which are bounded on both sides by the dunite. For convenience, the occurrence of the corundum in these alteration products between the dunite and the gneiss will be designated as a contact-vein and the other as a dunite-vein. The bounding walls of a dunite-vein are not necessarily of dunite; but may be of serpentine, the common alteration product of this mineral.

Where the corundum is found in the contact-vein, the following sequence is usually observed in a cross-section extending from the gneiss to the unaltered dunite:

a. Gneiss, hornblendic or micaceous, apparently unaltered.

b. Gneiss with same general appearance as *a*, but so decayed that the particles readily separate from each other.

c. Yellowish vermiculites, varying considerably in thickness, with a maximum of 6 or 8 inches, and in places entirely absent, so that *b* comes directly in contact with *d*. Where present, *c* often merges into *d*.

d. Green chlorite, varying in thickness much like *c*, and absent entirely in places.

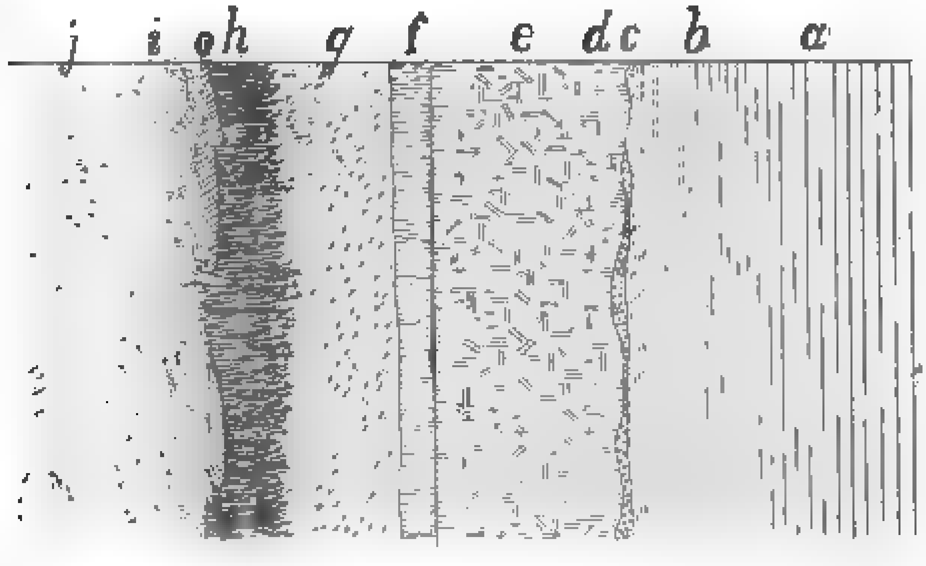
e. Chlorite and corundum. Sometimes with a little vermiculite. In places this mass may be largely of corundum, and it is what is called the "corundum vein," varying in thickness from a few inches to 12 or 15 feet.

f. Green chlorite. As far as observed, always present, and varying from 1 to 12 inches in width.
g. Enstatite; in places hard and compact, several feet wide; in other places only a few inches wide, usually merging into *h*.
h. Talcose rock, usually fibrous, varying from a few inches to several feet in thickness.
i. Dunite, more or less altered, friable and stained with ferric oxide.
j. Dunite, apparently unaltered, quite extensive.

Between *h* and *i* a seam of yellowish clay is sometimes observed which often contains a narrow seam or fragments of chalcedony.

From what could be learned from actual observations and inquiry among the miners, *c* and *d* are sometimes absent, and when this is the case, *e*, a mixture of chlorite, vermiculite and corundum, is seemingly in direct contact with *b*. The chlorite, however, on the dunite side of the section is constant. The thickness of the several zones (*a*, *b*, *c*, etc.) in such sections varies greatly at different places; and the distance across such sections may be said to vary at different points, even in the same region, from a few feet to 30 or 40 feet. The accompanying diagram (fig. 5) represents the cross section of a contact vein observed at Corundum Hill.

5.



In the diagram, fig. 5, *a* represents gneiss, apparently fresh and unaltered, passing into *b*, which has somewhat the appearance of the unaltered gneiss, but is so decayed that the particles readily separate from each other; *c*, narrow zone of vermiculites that sometimes is entirely lacking; *d*, green chlorite, clinochlore, partially decomposed and forming the vermiculites of *c*; *e*, the corundum-bearing zone, a mass of the green chlorite with crystals and fragments of corundum dis-

seminated through it; *f*, another zone of the green chlorite; *g*, mass of interlocking bladed grayish crystals of enstatite that merge into *h*, a fibrose talcose rock which passes into *i*, an altered dunite that is somewhat friable and stained with ferric oxide; *j*, hard and apparently unaltered dunite. Between *h* and *i* a mass of soft, yellowish clay, *o*, containing fragments of chalcedony.

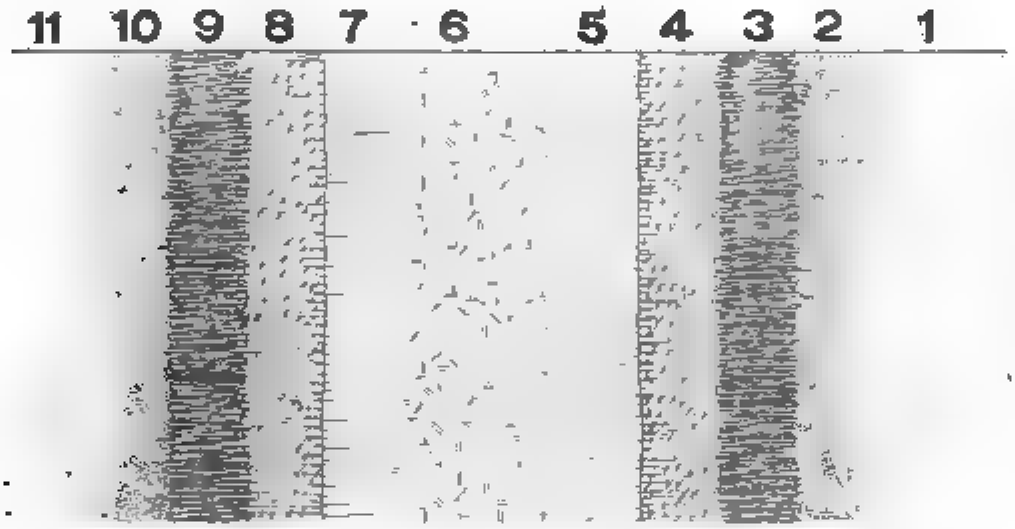
The line of contact between the zone of alteration products and the gneiss was very sharp and distinct in all the contact-veins examined. The minerals developed between the corundum-bearing zone and the dunite are of great abundance and different from those between this zone and the gneiss.

In a cross-section of a dunite-vein at a shaft near the southern part of Corundum Hill, in a distance of from 20 to 25 feet, the following has been observed:

1. Dunite, hard and apparently unaltered.
2. Dunite, somewhat friable and discolored, passing into 3.
3. Talcose rock, fibrous, merging into 4.
4. Enstatite, grayish and somewhat fibrous.
5. Green chlorite, 6 to 15 inches in width.
6. Green chlorite, corundum and spinel, 6 to 8 feet wide.
7. Chlorite (same as 5).
8. Enstatite (same as 4).
9. Talcose rock (same as 3).
10. Dunite (same as 2).
11. Dunite (same as 1).

The similarity of the two parts of the vein, each side of the corundum zone, as described above and illustrated in fig. 6, is very apparent.

6



In fig. 6, 1 and 11 represent the apparently unaltered dunite; 2 and 10, dunite somewhat friable and stained and passing into 3 and 9, a fibrous talcose rock, often carrying a green

actinolite and some green chlorite; 4 and 8, a grayish, rather fibrous, enstatite rock that merges into 3 and 9; 5 and 7, green chlorite passing into 6, a mass of chlorite, corundum and spinel.

Although the section just described represents a particular one, it was observed that in all of the dunite veins, the character of the vein was the same on each side of the corundum-bearing zone. As has been stated already, either a talcose or serpentine rock may be the limit of the cross section. In one of the dunite veins at Corundum Hill, near the west end of the outcrop, the zone of corundum, chlorite and vermiculites is in direct contact with a serpentine rock both on the hanging and foot wall. This zone is divided, and in one place almost pinched out by a mass of serpentine rock.

The appearance and character of the veins vary according as they are contact-veins or dunite-veins. In a dunite-vein the approximate trend of the vein is towards the center of the mass of dunite. As these veins penetrate the dunite mass they usually grow less and less in width until they pinch out. This is especially a prominent feature at Buck Creek, Clay County, N. C., and at Laurel Creek, Rabun County, Ga.

In a contact-vein, however, the corundum seems to extend downward indefinitely along the line of contact. Supplementary-veins are often encountered branching off from a contact-vein, toward the center of the dunite, and these, like the true dunite-veins, grow less and less in width until they pinch out entirely. This variation in the occurrence of the corundum in the different veins has been observed by many of those who have prospected for and mined corundum in this region.

Discussion of the Problem.—The theory advanced by the author, as given in the introduction, is that the corundum was held in solution in the molten mass of the dunite when it was intruded into the country rock and that it separated out among the first minerals, as the mass began to cool.

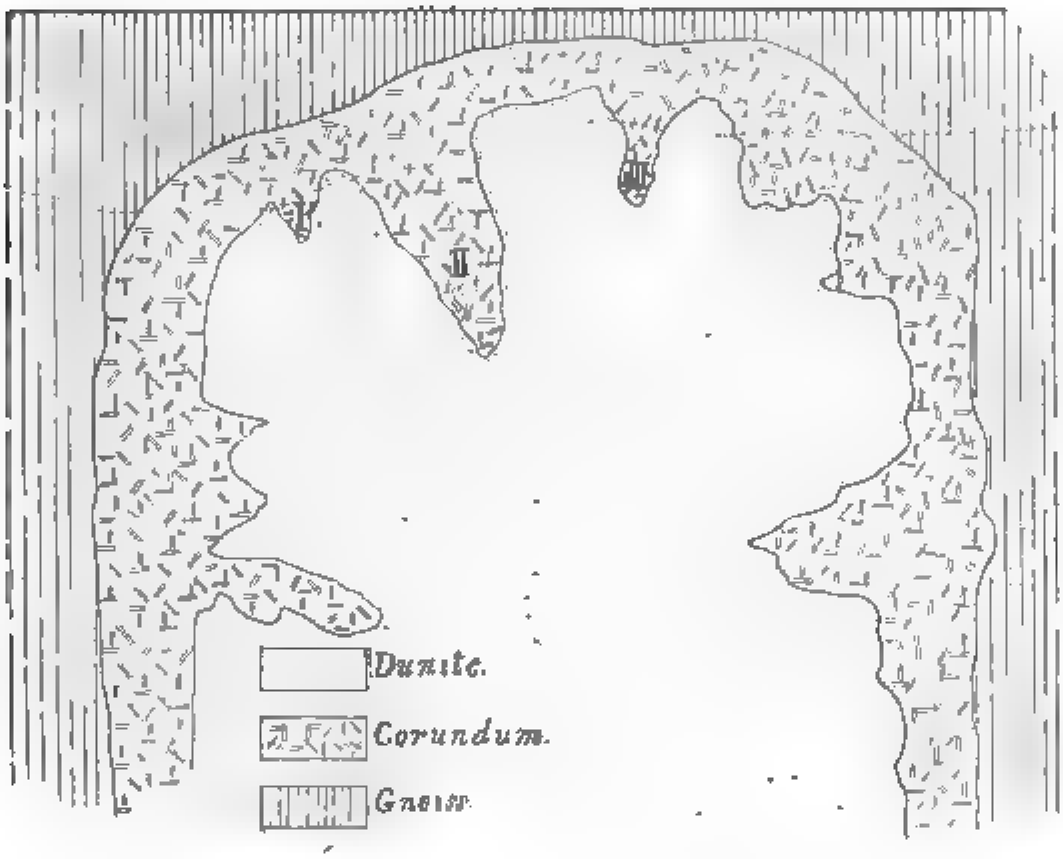
The dunite magma holding in solution the chemical elements of the different minerals would be like a saturated liquid and as it began to cool the minerals would crystallize out, not according to their infusibility but according to their solubility in the molten magma. The more basic portions, according to the general law of cooling and crystallizing magmas, being the most insoluble, would therefore be the first to separate out. These would be the oxides containing no silica, which in the present case would be alumina and chrome spinel and the corundum.

Morozewicz* has shown by some very important experi-

* Zeitschr. für Kryst., vol. xxiv, p. 281, 1895.

ments that molten glass of a character similar to the basic magnesian rocks would dissolve alumina readily, and as this molten mass began to cool corundum and spinel were the first minerals to separate out. According to this, the corundum and spinel would be the first to crystallize or solidify out from the molten mass of the dunite as this began to cool, and this would take place first on the outer border of the mass, because here it would cool first. Convection currents would then tend to bring a new supply of material carrying alumina into this outer zone, and when this zone was reached, crystallization would take place and the alumina would be deposited as corundum.

7.



This is essentially the idea advanced by Becker* in a paper on "Fractional Crystallization of Rocks," and where this process has taken place in dikes and laccolites, a concentration is observed of the earlier and more basic minerals at their outer boundary.

The more basic the magma the more fluid it is apt to be, and the more tendency there is for this process to take place, as shown by many well known instances which have been described by different geologists.

Figure 7 represents the author's idea of the appearance of a vertical cross-section of a mass of dunite, that held corundum

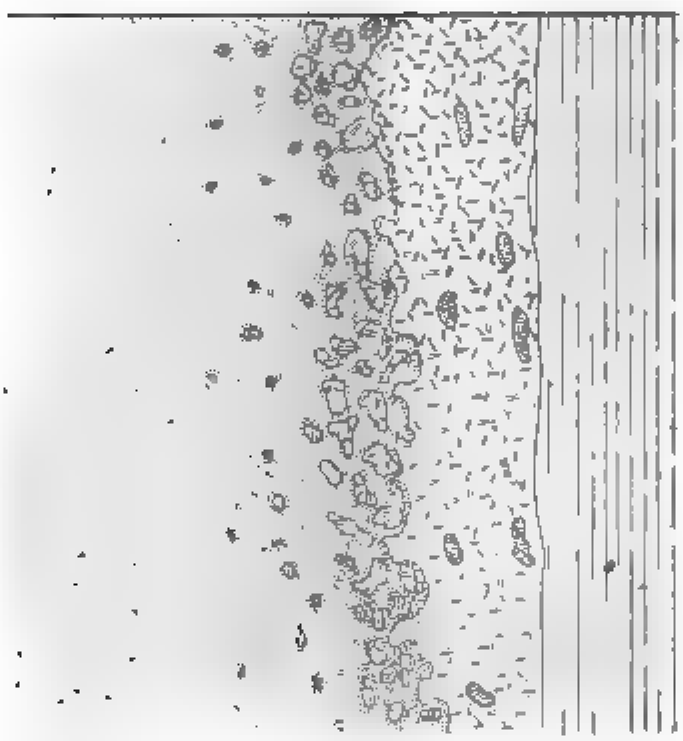
* This Journal, vol. iv, 1897, p. 259.

in solution, soon after its intrusion into a gneiss. In this figure the corundum zone has been greatly exaggerated in order to better illustrate the cross-section. The corundum would be concentrated toward the borders of the dunite and would make a sharp and nearly regular contact with the gneiss. With the dunite, however, the contact would sometimes be sharp and regular, while at others there would be an irregular line of contact and masses of the corundum would penetrate into the dunite.

The rapid erosion to which the rocks in this mountain region have been subjected would readily wear them down to their present condition, represented by the dotted lines in fig. 7.

The dunite-veins, I, II, and III in fig. 7, which at the present time have no connection with each other but are each separate and distinct, were at the time of their formation part of the corundum concentrated along the border of the dunite. Some of these veins would soon be worked out, while others might be explored for a hundred feet or more without any apparent change in their width.

8



Dunite. Corundum. Gneiss.

This explanation will account for all the variations in the occurrence of the corundum in the different veins.

The corundum crystallizing out from the molten dunite, which would be a very basic magma, would be concentrated toward the margins and where in many cases there would be a sharp separation (at the time of formation) between the corun-

dum and the dunite, in others there would be a somewhat gradual passage from the corundum to the pure dunite, as illustrated in fig. 8.

The pressure and the temperature and other physical conditions would affect the crystallizing and the separating out of the minerals from the molten mass, and this will explain the great variations observed in the corundum found in the same mass of dunite. Thus, at Corundum Hill there occur masses of block corundum, large rough crystals, small well-developed crystals, and particles or grains of corundum.

The differentiation of the basic dunite magma upon cooling is similar to what Vogt* and Adams† have described concerning the separation of sulphide deposits from a molten gabbro magma. The segregation or concentration of these ores is usually near the contact of the gabbro with the gneiss and is always sharply separated from the gneiss. While there is sometimes a distinct line of separation between the ore and the gabbro, at others there is a gradual transition from the ore to the pure gabbro. It might be expected that the corundum would be found surrounded by the dunite, but as was stated on page 55, there is but one locality known to the author where the corundum is found directly in the dunite. The absence of any general occurrence of the corundum in dunite is readily explained by the ease with which the dunite itself suffers decomposition.

The corundum concentrated in the dunite near the contact with the gneiss, where the thermal waters coming in contact with the heated masses would have the best chance to act, would furnish alumina for reacting with the dunite to form the aluminum-magnesium silicates found surrounding the corundum. That the dunite decomposes very readily is apparent from the numerous specimens found of the dunite completely surrounded by foreign material that must have been formed at its expense. The corundum has been found in the serpentine but this is often surrounded by chlorite.

The descriptions of the cross sections of the corundum veins given on pages 57–60 are similar to those described by Shepard‡, Chatard§ and Lewis‖, and show practically the same sequence.

As the dunite and corundum began to alter and decompose by the action of atmospheric agencies and thermal solutions, there would be formed a series of decomposition minerals on

* Zeitschr. für Prak. Geol., Nos. 1, 4 and 7, 1893.

† On the Igneous Origin of certain Ore Deposits; read before the Gen. Min. Asso. of the Prov. of Quebec, Montreal, Jan. 12, 1894.

‡ This Journal, III, iv, p. 111, 1872.

§ U. S. Geol. Survey, Bulletin 42, p. 49, 1887.

‖ N. C. Geol. Survey, Bulletin 11, p. 93, 1896.

the dunite side of the vein and but a few on the gneiss side. The decomposed material that would be found on the gneiss side of the vein would vary according to the amount of the dunite that had been held between the corundum and the gneiss (fig. 8). The common decomposition product surrounding the corundum is the chlorite (clinochlore) or a further alteration of the mineral to the vermiculites.

Between the corundum imbedded in the chlorite and the gneiss there is often but very little and at times no chlorite or vermiculites developed, the corundum-bearing portion of the zone being apparently in direct contact with the gneiss (*b* of cross-section, p. 58).

In the dunite veins the alteration products developed are the same on both sides of the corundum-bearing zone and are in most cases nearly an exact reproduction of the dunite side of a cross section of a contact-vein (figs. 5 and 6). This demonstrates that the gneiss had no influence in the formation of the alteration products of the contact-veins.

The analyses of Chatard* which show the chemical character of the vein to increase in magnesia and decrease in alumina as the dunite is approached, are in accord with the present theory regarding the formation of the alteration products.

The penetration of molten material carrying corundum into the gneiss during the differentiation of the molten dunite, would explain the occurrence of any corundum found in the gneiss bordering a contact vein. There is a similar occurrence of the sulphides penetrating into the gneiss during the cooling and differentiation of a molten gabbro, which is well illustrated in Vogt's* article and have been reproduced by Adams.†

Pirsson's‡ theory regarding the origin of the Montana sapphires, occurring in a basic igneous dike,§ is that these crystals separated out from the molten magma as this began to cool. He points out that originally the rock could not have been sufficiently rich in alumina to have allowed a general separation out of that material, and undoubtedly the magma took up quantities of inclusions from the sediments through which it passed. Clay shales, or a rock of similar composition, must have been among these sediments; and the fragments of this shale would be dissolved by the basic magma from which on cooling the alumina would separate out as corundum.

Summary.—This theory of the igneous origin of the corundum associated with the peridotites is in accord with the field

* U. S. Geol. Survey, Bulletin 42, pp. 50–56.

† Already cited.

‡ This Journal IV, iv, p. 422, 1897.

§ This Journal III, l, p. 467, 1895.

observations, the most important of which are the occurrence of the corundum surrounded by granular dunite and also by serpentine; its occurrence with and surrounded by spinel; the sharp contact between the gneiss and the alteration products of the contact-vein; the same sequence of alteration products which are found on both sides of the corundum-bearing zone of a dunite-vein and which are almost identical with the dunite side of a contact-vein; the usual narrowing and pinching out of the dunite-veins, the trend of which is toward the center of the mass of dunite; while the contact-vein seems to extend downward indefinitely.

The laboratory experiments of Morozewicz* and Logorio† into the solubility of alumina in a molten basic glass and the separating out of the corundum and spinel as the first minerals when the glass began to cool, also give strong support to the igneous theory of the origin of the corundum accepted by the author.

Thus the facts obtained in the field and in the laboratory both point to the same conclusion regarding the origin of the corundum associated with the peridotite rocks.

In conclusion the author desires to express his thanks and indebtedness to Prof. L. V. Pirsson of the Sheffield Scientific School for valuable aid in the preparation of this paper.

N. C. Geological Survey, March, 1898.

* Cited on p. 60.
† Zeitschr. für Kryst., vol. xxiv, p. 285, 1895.

Art. VI.—*Erionite, a new Zeolite;* by Arthur S. Eakle.

The mineral described in the present paper occurs in a rhyolite-tuff from Durkee, Oregon, and was discovered and presented to the museum for identification by Mr. E. Porter Emerson. The tuff consists of a dull gray, amorphous groundmass containing numerous patches of light brown, pitchstone-like material, fresh sanidine and plagioclase crystals, with an occasional dark silicate altered to chlorite. Large masses of opal fill the cavities. This opal is mostly of the milky and hyalitic kinds, yet often grades into a beautiful precious variety, showing a rich play of colors and forming excellent gem material.

The zeolite occurs as very fine threads, having a snow-white color and pearly luster. These threads resemble fine woolly hairs, having the same curly nature and soft feel. They occur, sometimes as white tufts firmly adhering to a solid base of milky opal, resembling a filamentous growth of the opal, and sometimes as compactly matted fibers filling the rock fissures. In some of the specimens, the filaments are encrusted with a thin shell of white opal, indicating that the opal was subsequently formed from the zeolite.

The mineral fuses easily and quietly in the Bunsen flame, to a clear colorless glass. Heated in a closed tube, the fibers darken slightly, emit a burnt odor, and give off much water which reacts strongly alkaline. The tuff also shows this alkaline reaction, so it is evident that organic matter of some sort is present in the rock. The organic substance in the zeolite must be a part of its constitution and not a contamination of any hydroscopic water, since it cannot be eliminated by long boiling in water or acids.

The weight of the fibers fluctuates materially from the influence of the air, making correct weighings difficult. The loss over sulphuric acid is water of crystallization, as evidenced by the rapidity with which such loss is regained on exposure. Two-thirds of a gram of the material which had been exposed to the air of the laboratory for two months, was weighed in a platinum crucible and placed in a desiccator for a week. At the end of this period the loss was 6·95 per cent; in one hour, on the balance pan, one-half of this loss was regained; in two and a half hours, the fibers reached their original weight; in four hours, their weight became stationary and exceeded the original weight by 60 milligrams, although the weighings were made in a warm dry room and the balance case contained a beaker of strong sulphuric acid. In the air bath at 110° C.,

the loss was 7·68 per cent; at 200° C. it amounted to 13·32 per cent; at 280° C. it was 15·25 per cent, of which last all but 2 per cent was regained over night, when placed under a beaker in the laboratory. The loss was practically constant for the different temperatures, as shown by repeated trials and different durations of heating. All water of crystallization was apparently expelled at 280° C., for on further heating up to 400° C. no more loss was experienced. The remaining water was expelled at low red heat, without fusion, the total loss averaging 17·30 per cent. This makes a difference of about 2 per cent as probably constitutional water. Alkaline water was still given off at 200° C., but at 280° C. all evidence of ammonia had disappeared. The water of crystallization evidently contains the organic substance, and considering the ease with which the fibers absorb moisture, it is readily conceivable that such moisture may have carried a certain amount of organic impurity into the mineral. The amount of ammonia was determined by combustion with soda-lime, collecting the gas in standardized H_2SO_4 and titrating with KOH solution, the result being 0·22 per cent. While this amount is too small to affect the general formula of the silicate, even if considered an essential constituent, it is nevertheless sufficient to form an important pyrognostic characteristic. The fibers are soluble with extreme difficulty in HCl. Complete decomposition was effected by boiling them in concentrated acid, evaporating the solution to dryness, grinding the residue and again boiling, the silica in the end separating as a fine sand, with no gelatinization. In the analyses, decomposition was effected (1) by fusing the fibers with the mixed carbonates, (2) by first igniting to a glass and then fusing with the carbonates, and (3) by dissolving in HCl. These various analyses were sufficient to establish the molecular ratio of the mineral, although from the nature of the material, closely agreeing duplicates were difficult to obtain. An average of the analyses gave

			Ratio.	Calculated for $6SiO_2 . Al_2O_3(Ca_1K_2Na_2)O + 6H_2O$
SiO_2	57·16	= ·953	6·03	56·52
Al_2O_3 ...	16·08	= ·158	1·	16·01
CaO	3·50	= ·062	1	4·40
MgO	0·66	= ·017		
K_2O	3·51	= ·039		3·69
Na_2O ...	2·47	= ·040		2·43
H_2O	17·30	= ·960	6·07	16·95
Total..	100·68			100·00

Here the ratio $Si:Al_2 = 6:1$, $Si:H_2 = 1:1$, $R:Al_2 = 1:1$,

while $Ca+Mg:K_2:Na_2 = 2:1:1$. This gives a general formula $6SiO_2, Al_2O_3(CaK_2Na_2)O+6H_2O$, or allowing one molecule of water as hydroxyl, $H_2Si_6Al_2CaK_2Na_2O_{17}+5H_2O$. The general formula is analogous to that of stilbite, in which the calcium has been largely replaced by the alkalies, but in other respects the zeolite has no resemblance to stilbite and is undoubtedly a distinct mineral. The specific gravity is 1·997, determined by the methylene iodide and Thoulet solutions. Unfortunately the filaments are so delicate that complete optical determinations cannot be made. The mineral has a moderately strong double refraction. The acute bisectrix lies parallel to the fibers, since an axial figure normal to the obtuse bisectrix can be seen in the fibers. The axis of least elasticity is apparently in the direction of the fibers, making the mineral positive in character. Extinction is exactly parallel and indicates an orthorhombic crystallization. Several attempts were made to get a cross section of a bunch of the fibers, by imbedding them in various media, but nothing in the way of an axial figure was obtained. No difference was observed in the polarization colors between the fibers heated to 280° C. and those not heated.

The name *erionite*, from ἔριον, wool, is proposed for the zeolite, on account of its woolly appearance.

An analysis of the milky opal associated with the mineral gave SiO_2 95·56, H_2O 4·14 per cent and a trace of alumina.

Mineralogical Laboratory, Harvard University, April, 1898.

ART. VII. — *The Winter Condition of the Reserve Food Substances in the Stems of certain Deciduous Trees;* by E. MEAD WILCOX.

THE investigations, of which this is a preliminary account, were undertaken to determine more definitely some of the essential physiological processes involved in the dormant periods of our woody plants. Stated briefly the problem was (*a*) to determine what are the conditions in which the reserve food substances are stored in the twigs during these dormant periods, i. e. during the winter, and (*b*) what if any changes they undergo during this period, and (*c*) how do these changes affect the renewal of activity by the buds at the beginning of the subsequent season of growth.

And it is to be noticed that the phenomenon of the renewal of activity by buds is not essentially unlike the process of the germination of seeds—in fact both phenomena may well be classed under the one head of the germination of dormant organs.

It is well known that this periodic alternation in the vegetative growth of the tree of a period of growth and a period of rest is so regulated that both normally occur at definite seasons of the year. And this fact has led many writers to ascribe this periodicity to the effects of temperature and in general to external rather than to internal changes. However, these dormant periods often occur under the most favorable conditions both as to moisture and temperature, while germination and the renewal of vegetative activity quite as often occur under rather adverse external conditions. In fact more careful study tends to show that the apparently close dependence existing between vegetative rest and unfavorable external conditions is due to the fact that in the cells there are taking place certain remarkable changes that require for their completion a dormant period. This fact was definitely determined for the potato tuber by Müller-Thurgau '82, '85.

The two very interesting papers by Müller-Thurgau give the chemical changes that occur in the potato during its dormant period. In fact his work shows certainly a dependence of the renewed growth of the tuber upon the completion of these changes in the starch and other reserve food material stored within the tuber. Hartig, '58, expressed the view that the starch is stored in the cells of the bark and wood during the summer and that it remains there unaltered in position or amount till it is entirely or partially consumed in the production of new organs the following

spring. This has been the accepted view until within very recent times. Gris '66 and '66*a* also shared in this view and says ('66, page 443): "Qu'il n'y a que deux grandes mouvements des matières nutritives à l'interieur du tronc des arbres: la gênese de ces matières en ètè, et leur résorption au printemps." Famintzin and Borodin, '67, noted in their study of a birch (the species is not given) that there was a rapid formation of starch in the spring in the cells of the male catkin and in the young twigs in both of which there had been no starch during the winter. They suggest that this starch might have been formed from the oil that was stored in abundance in the same regions and that gradually disappeared during the period of starch formation.

Schroeder, '69, in his paper on *Acer platinoides* came to much the same conclusion, so far as concerns starch, as did Gris. Grebnitzky, '84, studied eighteen species of trees for a period of two years but came to quite different conclusions than either of the others mentioned above. He says (l. c., page 157): "Die Stärke wird im Herbst audgespeichert, bleibt jedoch während des Winters nicht als solches erhalten, indem sie wahrscheinlich in Fett übergeht, in Frühlinge erscheint sie vor dem Knospenbruche wieder." By this we see that Grebnitzky recognized two periods of starch maximum alternate with two periods of starch minimum in the twigs. He says further that in all the soft-wood trees, as the Linden, all the starch disappears in winter while in the hardwood trees that the starch in the bark only is replaced.

Baranetzky, '84, held that this change of starch into oil is a process that takes place only in the presence of active protoplasm and that it goes on faster at higher temperatures than at lower temperatures. And this last assumption seemed to him to explain the fact that the transformation of starch into oil does not take place in roots at all or at least not to such an extent as in stems and all parts above ground. This seems to me to be a mere assumption that does not adequately explain the conditions he considers to exist. Russow, '84, carried on some experimental work in several species of trees. He records a gradual reduction in the amount of starch in the bark and considers that it was replaced by oil. He thought that the amount of starch in the woody part of the stems remained the same during the winter. He further says that the starch reappeared in the bark in the course of a week in the spring.

Fischer, '88 and '90, comes to the conclusion that there exists an autumn and a spring maximum period as to the amount of starch in the twigs. He divides the species that he examined into two classes distinguished by the starch in one case changing into oil and in the other into glucose. For further details

the reader is referred to the original paper as it is too lengthy to review properly in full in this preliminary paper

My studies during the past year have been largely confined to the question of starch formation and distribution and its relation to the growth of the tree. And in this preliminary communication I purpose giving some of the results so far obtained that throw light upon this particular subject.

The following list includes the names of the species which I have studied: *Gordonia altamaha*, *Æsculus flava*, *Æsculus flava purpurascens*, *Æsculus glabra*, *Æsculus lyoni*, *Sassafras officinale*, *Asimina triloba*, *Celtis occidentalis*, *Ailanthus glandulosus*, *Syringa vulgaris*, *Magnolia umbrella*, *Magnolia conspicua* (hybrid), *Acer saccharinum*, *Diospyros virginiana*, *Euonymus atropurpureus*, *Cratægus tomentosa*, *Cornus florida*, *Fagus ferruginea*, *Pyrus malus*, *Rhododendron maximum*, *Rhododendron punctatum*, *Cladrastris tinctoria*, *Lindera benzoin*, *Liriodendron tulipifera*, and *Hamamelis virginiana*. In addition to the above twenty-five species a number of others have been examined from time to time.

I have collected material* from each of the above species at intervals of one or two weeks since the first of October, 1897. Buds and sections of the stem were collected each time and preserved in the same bottle for further study. A variety of fixing reagents have been employed but none gave so good results as the following two: (1) a saturated solution of picric acid and corrosive sublimate in 95 per cent alcohol and (2) a saturated solution of corrosive sublimate in 95 per cent alcohol. In the former case washing out was accomplished with weak alcohol and in the latter case the sublimate was removed with water. All the material after thorough washing was placed in 50 per cent alcohol for preservation or imbedding. It was found desirable in the study of protoplasmic connections to fix the material in the osmic-acid-uranium-acetate mixture first recommended by Kolossow† and employed by Gardiner‡ for this purpose.

Imbedding was accomplished either in a soap mixture or in paraffine. For the details of the former method the reader is referred to my recent paper§ on that subject. By the use of the following paraffine method I was able to obtain perfect serial sections of buds as thin as 6⅔ or 10^{mm}. The buds are thoroughly dehydrated in absolute alcohol and then an equal volume of chloroform is added to the alcohol and the material

* My thanks are due Mr. J. G. Jack of the Arnold Arboretum for assistance in the collecting of material.

† Zeit f. wiss. Mik., v, 50–53, 1888.

‡ Proc. of the Royal Society, lxii, 100–112, 1897.

§ Journ. of Applied Mic., i, 68–69, 1898.

is to remain in this mixture for about six hours or more. It is then placed in pure chloroform for about the same time; at the end of which time it is transferred to a solution of paraffine in chloroform and allowed to remain for about a week in this solution. Complete infiltration in the melted paraffine can now be secured in half an hour to an hour. By this method beautiful ribbon sections are easily cut on the Minot-Zimmermann microtome. These ribbons are fastened to the slide by the usual albumen fixative.

Staining was accomplished by one of the following methods—the particular method depending upon the character of the cell contents to which I desired to give special attention. In the study of the leucoplastids and proteids crystalloids one of the methods given by Zimmermann* was followed. His acid-fuchsin "method B" is well adopted to staining single sections while for staining on the slide the method of Altman is better. Mann's methyl-blue-eosin method was found serviceable in the study of proteid crystalloids as well as for general cytological purposes. This method was employed by Lily H. Huie† in the study of proteid crystalloids, and as the article appears in a periodical that is not everywhere accessible I will give the details of the method here. Two solutions are first made as follows:

A.	1 per cent solution of methyl-blue in water	35^{cc}
	1 per cent solution of eosin in water	45^{cc}
	Water	100^{cc}

B. 1 per cent solution of NaOH in absolute alcohol.

Sections are to be stained for twenty-four hours in A and then rinsed in water and dehydrated up to absolute alcohol. The sections are now placed for a few minutes in thirty cubic centimeters of absolute alcohol to which a few drops of B has been added. The NaOH is then removed from the sections with absolute alcohol and they are then rinsed for one minute in water. Red clouds are here given off and the sections become blue again. They are now placed in water slightly acidulated with acetic acid to deepen and restore the blue color and to fix the eosin in them. They are now dehydrated, cleared with xylol and mounted in balsam. In the special study of the protoplasmic connections several stains were employed but these methods will not be given here.

Before proceeding to the discussion of the results so far obtained and their bearing on the general subject of the dormant periods of plants, I will give in some detail the facts observed in the study of two species, *Liriodendron tulipifera* and *Pyrus malus*.

* Microtechnique (Trans.), p. 195–198, 1893.
† La Cellule, xi, 27–52, pl. i, '95–'96.

Material of the *Liriodendron* collected on Oct. 20, 1897, was upon examination found to have an abundance of starch in the cells of the cortex but none in the cells of the medullary sheath and but few grains in the cells of the wood parenchyma and medullary rays. The cells immediately below the growing point of the stem contained no starch at this time. At this time practically all the leaves had fallen and the amount of starch now present represents the maximum amount. An examination of twigs from the same tree during the months of November and December showed a gradual increase in the amount of the starch in the medullary sheath but a marked decrease in the amount present in the cortex. During all this time there was some starch in the wood parenchyma and even more in the medullary rays. There was at this time a considerable amount of starch in the pitted cells that form plates across the pith in this species; but none was found in the other cells of the pith, which latter had no protoplasmic contents. The cells below the growing point up to this time contain no starch and in fact none is found there till about the first of March. The January collections show a gradual reduction of the amount of starch in the cells of the wood parenchyma and the medullary rays and medullary sheath. We reach finally a period at the end of February when starch begins to appear again in the cortex but more especially in the cells which lie beneath the growing point, i. e. in that dome-shaped group of cells that is called the pith cap. The cells of this cap are much the same in histological structure as those of the medullary sheath. The last collections, those of March, show still more starch in this region above the pith cap and less in the medullary sheath with quite a large quantity in the cortex.

The same statements will hold good for *Pyrus malus* except that some starch was found in the medullary sheath, medullary rays and the wood parenchyma on Oct. 20, 1897. In this species some starch could be found in the cortex all winter but in other respects the starch distribution was much the same as in *Liriodendron.*

The facts just stated for these two species will hold good, with slight individual variations, for the other species examined. In trees growing under our conditions I have found no such marked reduction in the total amount of the starch in the twigs as was reported by Fischer, '88 and '90. The only alterations I find are simply a general movement of the starch from the more peripheral and exposed regions to the more deep-seated and protected regions of the stem during the winter and a return again in the spring to the cortex and the regions of growth.

Further studies, now in hand, will trace the condition of the

starch and other cell contents throughout the entire year. Two associated questions are being examined in connection with the foregoing, (1) the determination of the behavior of the leucoplastids in the starch-bearing cells in the stems of our deciduous trees during this period of dormancy, and (2) the part which the intercommunicating threads of protoplasm play in the translocation of starch.

Questions in regard to the partial transfer of protoplasm itself inward from the cortex and back again at certain periods are being incidentally examined.

The slight changes in the reserve food material during the period of dormancy have an important bearing on the interesting speculation as to the relation existing between plants of temperate climates and their possible ancestors which thrived under the conditions of a warmer and more equable climate. The relations of all this to the question of biological protections are sufficiently obvious.

Botanical Laboratory of Harvard University, May 14, 1898.

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ART. VIII.—*Metamorphism of Rocks and Rock Flowage*; by C. R. VAN HISE.

[Condensed by the author from the Bull. Geol. Soc. Am., vol. ix, 1898, pp. 269–328.]

THE paper of which this is condensed is adapted from a partly written treatise on the subject of metamorphism and the metamorphic rocks.

In the article some of the more important physical and chemical principles which concern the alterations of rocks are summarized, and these principles are applied to the alterations which occur in connection with dynamic action.

SUMMARY OF PHYSICO-CHEMICAL PRINCIPLES.

The agents through which the alterations of rocks take place are water solutions and mineralizers. In the present discussion mineralizers will not be considered.

Below the level of the free surface of underground water the rocks are practically saturated; above that level the rocks are not ordinarily saturated, but upon the average contain a considerable amount of water held by adhesion between the liquid and the solid mineral particles. Both below and above the free surface, water is the all-prevailing agent through which the chief alterations of rocks are accomplished.

The forces of metamorphism are (1) dynamic action, (2) heat, and (3) chemical action. In all of the various kinds of metamorphism ordinarily recognized in classification, such as hydro-metamorphism, static metamorphism, pressure metamorphism, dynamic metamorphism, regional metamorphism, contact metamorphism, and thermo-metamorphism, all of the forces above mentioned are required, and also the agent, water. There is no metamorphism of a rock without the presence of water, and hence all metamorphism is partly hydro-metamorphism; there is no metamorphism of a rock without motion, either molecular or mass, and hence all metamorphism in an exact sense is partly dynamic; there is no metamorphism of a rock without the presence of heat, and hence all metamorphism is partly thermo-metamorphism; there is no metamorphism of a rock in which chemical action does not enter, and hence all metamorphism is partly chemical metamorphism. When it is realized that in all the varieties of metamorphism mentioned, chemical action, heat, and dynamic action enter as factors, only in different degrees, and when it is remembered that water is the universal agent which is present and active wherever metamorphism occurs, it is self-evident that the classifications of metamorphism ordinarily given are not satisfactory.

A critical examination of the classifications of metamorphism shows that the kinds of metamorphism recognized in the textbooks are based upon the idea that the particular force or agent mentioned is dominant in the production of the particular metamorphism. However, the classifications involve different factors, not belonging to the same category. For instance, thermo-metamorphism refers to heat; contact metamorphism refers to the contiguity of an igneous rock; hydro-metamorphism refers to the presence of water. As a matter of fact, all of the different kinds of metamorphism are related in the most intricate manner, and certain kinds of metamorphism which have been called thermo-metamorphism might just as well be called hydro-metamorphism.

Underground Flowage of Water.

Underground water, the agent of metamorphism, needs to be considered from two points of view—(1) its movement and (2) its work.

(1) *Movement of underground water.*—The movements of underground waters are dependent upon (*a*) head, (*b*) the underground openings, and (*c*) viscosity.

(*a*) The flowage of underground water is caused by head. Head is due chiefly to difference in the level at which the water enters and issues from its underground course. It may, however, be partly due to difference in temperature in the descending and ascending columns.

(*b*) Openings in rocks may be divided into (1) openings which are larger than those of capillary size, (2) capillary openings, and (3) subcapillary openings.

To movements of water in openings larger than those of capillary size the ordinary laws of hydrostatics apply. To movements of water in capillary openings the laws of capillary flow apply. By subcapillary openings are meant those in which the attraction of the solid molecules extends from wall to wall, and in these flowage is either exceedingly slow or does not occur.

(*c*) The elements entering into viscosity are the concentration of the solutions and the temperature. The viscosity of water decreases very rapidly with rise of temperature, and hence the high temperature in the lower part of the zone of fracture is very favorable to flowage.

(2) *Work of underground water.*—The potency of water as an agent through which metamorphism may take place is due, according to the modern ideas of physical chemistry, to its capacity to separate substances which it holds in solution into their free ions. In this power of ionization it exceeds all other solvents.

In order that crystals shall grow during the metamorphism of rocks, it is necessary that the solutions shall be saturated or supersaturated at the immediate place of crystal growth. As underground there is always a superabundance of material present as compared with the amount of water, we may suppose that at a moderate depth below the surface, and especially in the smaller spaces, where movement is slow, the solutions are often saturated. In the laboratory it is a well known fact that under conditions of saturation, with a superabundance of material, the larger crystals grow at the expense of the smaller ones, and that this process goes on more rapidly in proportion as the temperature is high and the pressure is great. In rocks this principle explains the growth of large mineral particles at the expense of smaller ones.

Forces of Metamorphism.

The work of underground water is accomplished by the forces of mechanical action, heat, and chemical action.

Dynamic action.—No changes in rocks take place without movements of materials, small or great, for short or long distances. Wherever there is rearrangement of the elements, there must be movements; even in the case of a mineral passing from one form to an allotropic form, there is movement of the molecules.

Mechanical action assists water in its work by producing in substances a state of strain which may pass to the stage of pulverization. Moreover, dynamic action produces effects through chemical forces and heat and by the agency of water. The more important laws of the relations between pressure and chemical action are as follows: "If we compress a chemical system at constant temperature, there follows a displacement of the equilibrium in that direction which is associated with a diminution of volume. . . . Thus the solubility of a salt in water, e. g., will increase with the pressure, provided that the dissolving is associated with a contraction of the solution plus the salt, and, conversely, the solubility will decrease if the separation of the salt (from the solution) is associated with a diminution of the volume of the system." The first of these cases is that applicable to underground water solutions. "Moreover, those chemical forces are strengthened by compression which condition a diminution of volume; and those chemical forces are weakened by compression which condition an increase in volume."

Heat.—All metamorphism takes place through the assistance of heat. Nowhere upon the surface of the earth, nor within the earth, is the temperature absolute zero. The activity of the molecules, or their kinetic energy, increases in proportion

to the heat, and the chemical activity may be enormously increased by a slight increase in kinetic energy of the molecules. The temperature is therefore a most important factor in the rapidity of the changes of all kinds.

For instance, the activity of water is greatly increased by rise of temperature. A slight rise of temperature may increase its rate of solution several fold, or out of all proportion to the absolute change in temperature. At temperatures above 100° C., and especially above 180° C., the activity of water may increase to an amazing degree.

Heat for the alteration of rocks is derived (1) from deep within the earth by conduction, or by convection through water or magma, (2) from dynamic action, (3) from chemical action, and (4) from the sun.

Chemical action.—No change takes place without chemical action. By chemical action is meant the taking of material into solution, the deposition of material from solution, the interchange between materials in solutions, the interchange between materials in solutions and adjacent solids, and, finally, possibly the interchange of the adjacent solid particles. I say possibly, for such an apparent interchange is probably accomplished through the medium of a separating film of water, in which case the apparently simple reaction is really accomplished by transfers between the solutions and solids. In all these interchanges, including those of simple solution and deposition, according to the modern ideas of physical chemistry, the salts are separated into their ions, and it is by the migration of these free ions that the interchanges are accomplished.

Relations of chemical action, heat, and pressure.—The more important laws expressing the relation of chemical reactions and heat are as follows: "If we heat a chemical system, at constant volume, then there occurs a displacement of the state of equilibrium, and in that direction toward which the reaction advances with absorption of heat." "Those chemical forces which condition a development of heat, will always be weakened by an increase of temperature; and conversely, those which condition an absorption of heat will be strengthened by such an increase in temperature; and it is this fact which, primarily, gives the preceding proposition its universal validity." "If we heat the system therefore, the reaction which takes place will be accompanied by absorption of heat; if we cool the system, the corresponding reaction will develop heat." "On the whole, the preponderating chemical reactions at lower temperatures are the combinings (associations) which take place with the development of heat: while the reactions preponderating at higher temperatures are the cleavings (dissociations) which take place with the absorption of heat." This ast is van't Hoff's law.

"In general, in comparing substances which are chemically analogous, and soluble with difficulty, the heat of precipitation (= the negative value of the heat of solution) is greater the more insoluble the substance is."

Finally, the relations between heat, pressure, and chemical action in a solution may be generally expressed as follows: "Every change of one of the factors of an equilibrium occasions a rearrangement of the system in such a direction that the factor in question experiences a change in a sense which is contrasted with the original change."

Application of Physico-Chemical Principles to the Earth's Crust.

It is evident from the foregoing principles that within the superficial zone of rocks in which reactions take place directly under our observation, and within the deeper-seated zone in which reactions have taken place and later have been brought within our observation, there may be opposing tendencies. The changing factors in these two physico-chemical zones are temperature and pressure and consequently chemical action. Both of these increase with depth.

Upper Physico-chemical Zone.

The chemical reactions which occur within the upper zone of observation of the earth are at the lower temperatures referred to in van't Hoff's law. Hence near the surface the reactions usually, if not always, take place with the liberation of heat, according to the first part of van't Hoff's law. The pressure near the surface is small, and therefore the law of chemical reactions with the liberation of heat in the outer zone is the dominating factor.

Hence an alteration may take place which works with or against pressure. In the first case, both the chemical reaction and the compression in volume result in the liberation of heat; in the second case, the heat liberated is that developed by the chemical reaction minus that absorbed as a result of the work done in expanding the volume.

The upper physico-chemical zone is divisible into two parts, the reactions within which strongly contrast: (1) an upper belt, mainly above the level of underground water, which is generally known as the belt of weathering, where disintegration, decomposition, and solution are the rule, and (2) a lower belt of greater thickness, in which cementation of openings is the rule, and therefore a belt in which induration is one of the most characteristic features.

Lower Physico-chemical Zone.

From the surface to considerable depth below the surface, the temperature ever becomes higher, and consequently the temperature may become so high that the tendency for reactions to take place which result in the development of heat is less dominant. However, at moderate depth, under ordinary conditions, say at 9,000 meters, the temperature is not very high, probably in the neighborhood of 300° C. Thus the tendencies for reactions to take place under the first part of van't Hoff's law, rather than the second part, would generally still control for a very considerable depth if it were not for the enormous pressure. In the lower zone this ordinarily becomes the dominating factor, especially in places of mass dynamic action, and reactions take place which result in the production of less volume, the chemical forces which condition a diminution of volume being very active, and the chemical forces which condition an increase of volume being very weak or even overcome.

Relations of the Two Physico-chemical Zones.

In so far as energy is concerned, there are four cases: The chemical reaction may (1) release energy, and result in the liberation of heat; (2) may consume energy, and result in absorption of heat. The change of volume may be (3) by compression, and result in the liberation of heat, or (4) by expansion, and result in the absorption of heat. (1) and (3) will be called plus, and when they are combined the heat liberated is equal to their sum; (2) and (4) will be called minus, and when they are combined the heat absorbed is equal to their sum. When (1) and (4) or (2) and (3) are combined, heat may be liberated or absorbed, depending upon the relative values of the energy of the chemical reaction and that of the change of volume.

As a case in which the reactions as to temperature and pressure are each in opposite senses in the upper and lower physico-chemical zones may be mentioned hydration and dehydration. The first process occurs in the upper zone, and represents an association which takes place with the great liberation of heat, while the second process occurs in the lower zone, especially in connection with mass dynamic action, and represents a dissociation which takes place with important absorption of heat. The first process results in very considerable expansion of volume; the second process results in equivalent contraction of volume.

A second important reaction separating the outer crust of the earth into two physico-chemical zones is the mutual replace-

ment of oxygen and sulphur. In the upper zone oxygen replaces sulphur, and at the same time may largely oxidize that element. This results in great liberation of heat, and in some cases also in expansion of the volume of the solid compound, as in the case of the production of limonite. Oxidation may take place without replacing another element, as when iron protoxide is changed into sesquioxide with expansion of volume and liberation of heat. In the lower zone sulphur may replace oxygen with condensation and with great absorption of heat.

Another set of reactions of the most fundamental importance and widespread character, in which the first part of van't Hoff's law of chemical reactions and the law of pressure stand opposed to each other, and which occur in an opposite sense of the two physico-chemical zones, is the mutual replacement of carbon dioxide and silicon dioxide. Near the surface carbon dioxide replaces silicon dioxide, with great development of heat, and expansion, provided the freed silica separates as quartz. The general fact of the carbonation of the silicates under these conditions the world over is well known.

In the lower physico-chemical zone, and especially under mass dynamic conditions, silica replaces carbon dioxide upon the most extensive scale with great absorption of heat and with condensation, comparing the combined volumes of the original carbonate and silica with that of the resultant silicate. As illustrations of this may be mentioned the formation of wollastonite from pure limestone, of tremolite from dolomitic limestone, and of actinolite and grünerite from ankerite or from siderite. In the impure limestones under deep-seated conditions, where numerous bases are present, various complicated silicates form, such as other pyroxenes and amphiboles, and tourmaline, chondrodite, et cetera. As illustrating the very considerable condensation in silication wollastonite may be taken, the volume of which is 31·5 per cent less than that of the combined volumes of the calcite and silica from which it may be produced.

As a corollary to the foregoing pages is the conclusion that in the upper zone, where pressure is relatively unimportant, upon the average, alterations result in the expansion of the volume of the rocks; and in the deeper-seated zone, where pressure is important or dominant, upon the average, the alterations result in the contraction of the volume of the rocks. It follows as a further conclusion from this that the tendency of the alterations in the first zone is, upon the average, to produce minerals of lower specific gravity than the original minerals, while in the deeper-seated zone the tendency upon the average is to produce minerals of higher specific gravity.

Metamorphism from the Dynamic Point of View.

Dynamic action is of two kinds—molecular dynamic action and mass dynamic action. By molecular dynamic action is meant interchange between the molecules. Metamorphism by such interchange has generally been called static metamorphism. Molecular dynamic action is always accompanied in some degree by mass dynamic action. By mass dynamic action is meant deformation of the body of the rocks. To alterations in connection with such deformation the term dynamic metamorphism is usually restricted. Mass dynamic action is always accompanied by molecular dynamic action. It is recognized that there are all graduations between molecular dynamic action and mass dynamic action. However, in many regions the phenomena are produced mainly in connection with one or the other.

Molecular Dynamic Action.

Molecular dynamic action involves various degrees of movements.

(1) Presumably the lesser movements are the cases of change in crystalline form and of strain within the elastic limit. In the change of a substance from one crystalline form to another —as, for instance, of aragonite to calcite—the movement of the molecules may not involve more than a redistribution or re-arrangement of those which are adjacent. In the case of substances strained within the elastic limit the molecules are simply pressed slightly closer together or pulled slightly farther apart, and yet these very slight adjustments may have a most profound effect upon the physical properties of the materials.

(2) In a second class of movements there is a rearrangement of the chemical elements by which new compounds are produced from old compounds. Material may be added to or subtracted from a given mineral or from glass, or either minerals or glass may be altered into two or more other minerals, with the simultaneous addition or subtraction of material. The added material in any case may come from some other particle not far distant. The material subtracted in any given case may be added to another particle at a greater or less distance.

In the majority of changes by molecular dynamic action, under both (1) and (2), which come within our observation, the chemical reactions usually result in a liberation of heat or running down of energy, under the first part of van't Hoff's law. This may be illustrated by hydration, which is, perhaps, the most characteristic change of molecular action, such minerals as chlorite, kaolinite, zeolites and epidote forming abundantly.

The reverse chemical action, that taking place with the absorption of heat, occurs at great depth under mass static conditions.

The foregoing principles of alterations under molecular dynamic conditions are applied to the devitrification of glass and to the recrystallization of minerals.

Some of the more distinctive features of molecular dynamic action are the growth of large individuals and preservation or emphasis of previous textures and structures.

Mass Dynamic Action and Accompanying Molecular Dynamic Action.

It has already been stated that in connection with mass dynamic action, molecular dynamic action invariably occurs. The kind and amount of resultant metamorphism varies greatly, depending upon depth, upon the particular kind of deformation, and upon other factors. It has been shown in another place that, depending upon depth, there are three important zones of deformation of which we have definite knowledge: (1) An upper zone of fracture, (2) an intermediate zone of fracture and flowage, and (3) a lower zone of flowage.

Zone of fracture.—In the zone of fracture deformation is accomplished by considerable movements along surfaces or zones, with little or no movements between these planes or zones. Such fractures are faults, joints, fissility, bedding partings, and the spaces of autoclastic rocks. The rocks are broken by these fractures into great regular masses, blocks, or leaves or into the irregular fragments of a dynamic breccia. Into these openings water readily enters to assist in the modifications. The movements between the individual mineral particles are largely confined to thin layers along the walls of the openings, and the conditions may be here those of important interior deformation, but for the masses of rock between the fractures the conditions are those of molecular dynamic action already described, and the changes are correspondingly slow. The rapid changes are confined to the material adjacent to the openings. From the places of entrance waters may permeate the adjacent rocks to a greater or less distance, and consequently molecular dynamic metamorphism may occur to a much greater extent than it would be were it not for the fracturing. The alterations of the thin layers of material adjacent to the openings are by interior movements, which are in all respects like those of kneading described under the zone of flowage.

It follows from the foregoing that the deformation accomplished by widely spaced fractures does not result in the obliteration of the original textures and structures, except adjacent to the fractures. The rocks are merely jointed,

sliced, piled up, or brecciated, and in each block or slice the alterations are metasomatic, or those of molecular dynamic action.

Zone of combined fracture and flowage.—In the middle zone of combined fracture and flowage the alterations may combine those of fracture and of flowage.

Zone of flowage.—At the outset it may be said that the process of rock flowage is very different from the flowage of a liquid.

It has been explained in another place that in the deep-seated zone of rock flowage the process of deformation is similar to that of mashing or kneading. There every particle, small or great, takes part in the deformation.

As soon as interior movements begin, the destruction of the original textures and structures begins and goes on very rapidly, so that with comparatively little motion the original textures may be wholly destroyed. For instance, such rocks as quartzose sandstones, which retain their textures for indefinite periods if there be no mass action, even when buried under thousands of feet of other rocks, when deformed by mashing rapidly lose all clastic textures. In the same way the textures which are characteristic of igneous rocks rapidly disappear by mashing. In the place of the original textures, whether those of sedimentary or igneous rocks, there appear peculiar textures and structures referred to subsequently as characteristic of mass dynamic metamorphism.

During the interior mass movements of rocks water makes its way between the particles much more readily than under conditions of quiescence. This follows partly from the movements and partly from the heat developed by the movements. The increased temperature results in decreasing the viscosity of the water, and it has been seen that low viscosity is of great importance in the penetration of water through minute spaces.

Consequent upon interior mass movements two kinds of deformation occur, granulation and recrystallization. Between the two are all gradations. Where the movements result in granulation this exposes large surfaces to the action of the contained water. The dissolving power of water when not nearly saturated is almost directly in proportion to the area upon which it can act. One perhaps might expect that the more profound the kneading the finer would be the granulation of the altered rock, but this is not the case. Many of the most profoundly altered rocks, instead of being extremely fine grained, are somewhat coarsely crystalline.

It is generally agreed that the crystalline schists of this character have been recrystallized throughout, and therefore strongly contrast with those rocks which have been granu-

lated. However, the granulated and recrystallized rocks are not separated sharply from each other, but, on the contrary, there is every gradation between the two. If in the altered sedimentary rocks one passes from a place of granulation to one of recrystallization, he finds that recrystallization of the matrix begins while granulation of the larger particles is still going on. Whether granulation or recrystallization is the dominant process in a given place in the zone of flowage depends upon many factors. Some of these factors are the character of the material, water content, temperature, pressure, and rapidity of deformation. Refractory minerals are favorable to granulation; mobile minerals are favorable to recrystallization. Absence of water is favorable to granulation; presence of water is favorable to recrystallization. Low temperature is favorable to granulation; high temperature is favorable to recrystallization. The less the pressure the more likely is the deformation to be accomplished by granulation. The greater the pressure the more likely is the deformation to be accomplished by recrystallization. To a certain point, the more rapid the deformation the more likely is the adjustment to be by granulation. The slower the deformation the more likely is the readjustment to be by recrystallization.

Some of the more characteristic features of the crystalline schists are their evenness of grain, and the similar crystallographic orientation of the authigenic particles of some of the minerals.

In the recrystallization of rocks in the deep-seated zone adjustment may not lag far behind the disturbing forces. However, in most cases there is apparently some lag. In the most regularly laminated of the crystalline schists a close examination usually shows a slightly undulatory extinction, and therefore a state of strain in the minerals, showing that recrystallization has not exactly kept pace with deformation, or else that they have been somewhat deformed nearer the surface since recrystallization.

It is concluded that the development of the crystalline schists is to be explained as a process of chemical reaction induced by mechanical action, resulting in the constant solution and deposition of the material so as to accommodate it to the changing form of the mass.

Comparative energy required for deformation in the three zones, of fracture, fracture and flowage, and flowage.—The energy required for deformation in the three zones of fracture, fracture and flowage, and flowage, is discussed, and the conclusion is reached that the amount of work done, in order to produce the same mass deformation of the rocks, increases down

to the zone of recrystallization and then decreases for a certain depth. No conjecture is made as to how far down this decrease continues but it is believed to be probable that the decrease continues at least as deep as the zone in which the schists formed by recrystallization develop.

Meaning of Rock Flowage.

I have previously maintained that the rocks within the scope of our observation which have been deformed at considerable depths were deformed by rock flowage. However, I made no attempt to explain what actually occurred during the process. I shall take as a typical example of rocks which have been deformed in the zone of flow those laminated crystalline schists the mineral particles of which now show slight or no strain; for it is evident that these are the rocks which have nearly perfectly accommodated themselves to the deformation through which they have passed. The accommodation, as already explained, is accomplished by continuous solution and deposition, or by continuous recrystallization. While the adjustment during deformation at any moment was nearly as complete as though the rock were a magma, and while it nowhere shows more than a microscopic space, it is evident that the flowage is wholly different from that of a liquid. At no time was the rock a liquid. On the contrary, it was at all times almost wholly a crystalline solid. At no time was more than an almost inapplicable fraction of it in a liquid form—that is, dissolved in water—yet at all times it was adjusting itself by means of this small percentage of water contained in the capillary and subcapillary spaces, this being the medium of solution and recrystallization. In order that such a continuous process shall be adequate to explain rock flowage, it is necessary only that it shall be sufficiently rapid to keep pace with the deformation. One's first thought is probably that it is not possible that the process can be sufficiently rapid to account for the phenomena. However, the experiments of Barus upon the solution of glass give us a basis upon which we can make a quantitative calculation.

Barus has shown that a temperature of 180° C. is critical so far as the solution of glass by water is concerned. At temperatures lower than this the rate of solution by water is very slow. However, at temperatures of 185° C. and above, solution and crystallization of the silicates of glass go on with astonishing rapidity. In Barus' experiment water dissolved a sufficient amount of glass and deposited the material as crystallized minerals to cause an apparent contraction of volume of the water amounting to 13 per cent of the water present in the capillary tubes in 42 minutes and 18 per cent in an hour. This shows that solution continued during the later stages of

the experiment at about the same speed as during its earlier stages, for 13 : 42 about as 18 : 60.

During the experiment, unless hydrous minerals were produced, the water remained a constant quantity, and continued work. This could have been continued so long as the temperature and pressure were sufficient and glass was available for crystallization through solution, as a result of which the material is condensed. If no hydrated minerals are formed, there is no reason why a small amount of water cannot continue the process indefinitely.

If in this experiment we suppose the condensation of recrystallization to be 10 per cent, the amount of condensation in diabase in passing from the glassy to the crystalline condition, as shown by Barus, this would mean (neglecting the condensation of the water) that in one hour, in order to have given an apparent volume contraction of 18 per cent, the water had dissolved 1·8 times its own volume of the glass, and deposited crystallized material with 10 per cent less volume. Therefore, for the water to dissolve a volume of glass equal to that of the water and deposit it in a crystallized form would require $33\frac{1}{3}$ minutes, or approximately one-half hour.

During the process of deformation of the rocks the material, if not dissolved, may be strained even to the point of granulation by the mechanical processes; also so far as strain occurs, or the particles are small, the minerals are in a state in which solution is easier than for unstrained or larger mineral particles. However, it is probable that the solution of such mineral particles and the deposition of the material in an unstrained crystallized condition is considerably slower than that of amorphous glass, for it cannot be supposed that the same amount of energy is potentialized in the mineral particles as in the glass. But the further the strain goes before fracture the more energy is potentialized, or if fractures occur smaller particles are produced. Moreover, the contained water is in small capillary or subcapillary spaces, and therefore a given volume is acting upon a much larger surface than in the capillary tubes used by Barus in his experiments. In so far as granulation occurs, the surface for action is still further increased. All these conditions are favorable to solution and redeposition; therefore the greater the straining and resultant granulation, the more rapid the process of recrystallization; hence in the deep-seated zone mechanical disintegration never gets far in advance of solution and redeposition.

If it be supposed in the capillary and subcapillary spaces within the rocks that the speed of solution of minerals is ·1 of that of glass, water would dissolve its own volume of minerals and redeposit the material in about five hours. If the deep-seated rocks be supposed to contain 2 per cent of water by

volume—that is, less than 1 per cent by weight—the entire mass of rocks might be recrystallized in about 250 hours, or little more than 10 days. The percentage of water premised is known to be lower than the amount ordinarily found in the crystalline schists, and the rate hypothesized seems reasonable; but if this speed be decreased to ·1 of that suggested or ·01 of that of glass, still the entire mass of the rocks might be dissolved and reposited in about 100 days. Make the rate of ·1 of this or ·001 of that glass, and still recrystallization might be complete in about 1,000 days, or three years. It it be supposed that a mountain-making period occupied 150,000 years, and this is probably less rather than more than the time required for most mountain-making movements, during this period, at the slow rate suggested, the rocks could be recrystallized 50,000 times by 1 per cent of water, and this number certainly seems adequate to fulfill the requirement that at any given moment the crystalline rock shall exhibit but a slight strain effect.

Of course, it is not thought probable that any rock has completely recrystallized 50,000 times. Indeed, it is well known that many of the rocks in which recrystallization is complete, in so far as the finer particles are concerned, contain many larger particles which have not been completely recrystallized or even granulated.

If the case of a large grain of quartz or feldspar in a recrystallizing rock be taken, we may suppose the process to go on somewhat as follows: Because of the lack of homogeneity of the rock the stresses are irregularly distributed. At the most exposed places upon the mineral particles the conditions are favorable for solution, for the following reasons: the particles are there greatly strained, perhaps to the point of granulation, and, so far as strain exists or small granules are formed, these conditions are favorable to solution. At the places of great strain the material is therefore taken into solution and transported to the parts of the particles less strained. At such places the conditions are favorable to deposition, on account of the relatively large size of the residual original grains as compared with the granules. A mineral where least strained separates from the solution material like itself, attaching it to itself, in orientation with the core, in an unstrained or little strained condition. The process of growth is analogous to that of mineral growth by secondary enlargement. The entire process is similar in several respects to that of the continuous solution and deposition of calcium carbonate in the chemical laboratory when water is passed through a layer of this material under pressure. Where the pressure is greatest in the upper part, the grains are taken into solution. At the

place of escape, where the pressure is least, the material is deposited from solution, and the grains increase in size or grow.

During the deformation of the rocks this process of solution and deposition of a mineral particle is continuous. In this rearrangement it is not supposed that the identical molecules which are taken from the more severely stressed parts of a grain are necessarily deposited at the places of less stress upon the grain. Undoubtedly there is great interchange of material between the particles by means of the solutions. It is, however, thought probable that in many cases of deep-seated deformation, where the passage of solutions is difficult and slow, that much of the identical material which is taken from a grain at one place is added to it at another place.

When new individuals are produced in any way, as by granulation or by the deposition of new mineral particles, perhaps as different species from any originally in the rock, they are subject to the same laws as the original mineral particles. Many have a tendency to form with similar crystallographic orientation. However, it is only rarely that the orientation of the particles of a given mineral approximates exactness. One mineral—for instance, mica—may be well oriented, whereas such minerals as quartz or calcite may not be oriented.

In proportion as the minerals readily respond to the forces of recrystallization or are mobile, they do not gain or retain regularity of arrangement. After mass movement has ceased the temperature may be sufficiently high and the heat be held for a sufficient time, so that the solutions may completely recrystallize the minerals under mass static conditions, and therefore orientation may be lost. In proportion as minerals do not readily recrystallize or stubbornly resist the force of recrystallization, the minerals once oriented retain their regularity of arrangement.

It is concluded from the foregoing that rock flowage, as deep as observation extends, is plastic deformation through continuous solution and deposition, or, in other words, recrystallization. During the adjustment all or only a part of the material may have passed through this change. However, if a matrix, plastic by recrystallization, be filled with rigid granules which are not recrystallized, the whole mass may be deformed by true flowage of the matrix and by slipping or shearing readjustment of the granules. So far as the average mass deformation is concerned, the result is substantially the same as though each rigid granule had not acted as a unit. Indeed, the same average mass deformation may be accomplished wholly by granulation and welding, as in Adams' experiments; but it may, perhaps, be doubted whether this is ever strictly the case with rocks in nature, for some small amount of water is present, and probably, even in the case of

apparent perfect granulation, some degree of solution and recrystallization from solution has occurred. In the case of the imperfect crystalline schists, which are very widespread rocks, the adjustment to the new form is accomplished in part by the process of differential movement of rigid granules and in part by solution and redeposition. It is only in the case of the typical granulated rocks that we can suppose that the process of deformation is mainly accomplished by the movement of the solid particles over one another, and it is only in the perfect crystalline schists that we can suppose that the deformation is accomplished almost wholly by recrystallization.

Nothing is said by the foregoing conclusions as to the condition of the material below the zone of the crystalline schists or the meaning of the flowage of such material.

The conclusions of the foregoing pages show clearly the meaning of rock cleavage. I have already held that this structure is largely due to the similar crystallographic orientation of numerous mineral particles, and especially those which are authigenic, and therefore that rock cleavage is a capacity to part largely due to the actual cleavage of the similarly oriented mineral particles. As the cleavage of mineral particles has long been known to be a molecular structure, it follows that the cleavage of rocks is also largely a molecular structure. I have also explained that the similar crystallographic orientation is frequently, perhaps usually, accompanied by an arrangement of the mineral particles with their longer diameters in the same plane as the cleavage, and that this dimensional arrangement is a factor in rock cleavage, although one of probably less importance in most cases than that of the crystallographic orientation of the mineral particles.

Recrystallization and Aqueo-igneous Fusion.

It is apparent that the conclusions of the foregoing paper have an important bearing upon the hypothesis of aqueo-igneous fusion. It appears that if water is present when the material, as a result of the mechanical subdivision or for any other cause, reaches the very moderate temperature of 180° C., the adjustment is accomplished mainly by recrystallization, and that fusion is not necessary to account for the plasticity of the rocks.

So far as the typical crystalline schists themselves are concerned, it is certain that they are not the products of aqueo-igneous fusion. They have peculiar textures characteristic of themselves, which are wholly unlike textures of unmodified sedimentary rocks, and unlike those which are known invariably to appear in rocks which have crystallized from a magma, however the magma has been produced. Every magma crys-

tallizes according to the laws of magmas, and produces textures which are characteristic of such crystallization, and these are widely different from those of the crystalline schists.

It does not follow from the foregoing that the deeply buried rocks, including the crystalline schists themselves, may not become modified or even fused by contact with igneous intrusives.

Summary of Conclusions.

I here repeat some of the more fundamental principles stripped of qualifications:

(1) The chemical alterations which rocks undergo vary greatly under different conditions. The more important of these variable conditions are water content, temperature, pressure, and movement.

(2) The outer part of the earth, of which we have definite knowledge, may be divided into two physico-chemical zones. In the upper of these the reactions take place with the expansion of volume and with the liberation of heat, as end results. In the lower the reactions take place with the contraction of volume and with the absorption of heat, as end results. Some of the more important reactions in the upper zone are hydration, oxidation, and carbonation; some of the more important reactions in the lower zone are dehydration, sulphidation, and silication.

(3) The alterations under mass static conditions preserve previous textures and structures, but may go so far as to completely recrystallize the rocks. The alterations under mass dynamic conditions are different in the zone of fracture and the zone of flow. In the former the rocks are broken into fragments, and the alterations of the fragments are those of mass static conditions. In the zone of flow the alterations obliterate previous textures and structures and produce crystalline schists which have characteristic textures and structures.

(4) Rock flow is accomplished partly through mechanical strains, but mainly through continuous solution and deposition of the material of the rocks by the agency of the contained water. During the flow the rock is at all times almost wholly a solid, yet it responds like a plastic body to deformation without loss of its crystalline character, because of the continuous adaptation of the mineral particles, while in large parts retaining their integrity, to new forms by recrystallization.

(5) The energy required to produce a given mass deformation increases downward to the bottom of the belt of granulation. In the zone of flow by recrystallization the energy required to produce a given mass deformation is less, probably much less, than that in the lower part of the zone of fracture.

ART. IX.—*New Species of Ceratopsia;* by O. C. MARSH.

IN the series of *Ceratopsia* remains which I secured in the West for the U. S. Geological Survey, and have since sent to Washington, several forms new to science are represented. One of the skulls, the type of *Triceratops elatus*, was sent in 1891, and with it two others belonging to *T. prorsus* and *T. sulcatus*, and these are now on exhibition in the National Museum. Among the *Ceratopsia* skulls, twelve in number, sent to Washington from New Haven during the present month, are two of much interest, both representing new forms.

Triceratops calicornis, sp. nov.

One of these, which may be called *Triceratops calicornis*, is of special importance, as not only the skull but the greater part of the skeleton of the animal is in good preservation, forming one of the most instructive specimens now known of this group of extinct Reptiles. The skull as a whole shows the well-marked features of the genus *Triceratops*. A specific character is seen in the nasal horn-core, which is in perfect preservation. It is directed well forward, and unlike any hitherto described is concave above, which fact has suggested the specific name. The upper or posterior surface of this horn-core somewhat resembles the bottom of a horse's hoof.

Some of the principal dimensions of this skull are as follows: Length from front of beak to back of parietal crest, about six feet, five inches; from front of beak to end of occipital condyle, three feet, five inches; distance from occipital condyle to back of parietal crest, four feet; from front of beak to point of nasal horn-core, twenty-three inches; height of post-frontal horn-core, twenty-nine and a half inches, and antero-posterior diameter of same horn-core at base, twelve inches.

Triceratops obtusus, sp. nov.

A second new species, which may be called *Triceratops obtusus*, is represented by a large skull belonging to the same genus. The nasal horn-core of this skull is very short and obtuse, and so well preserved that it indicates the normal form and size. The entire length of this horn-core is only one inch. Its summit is three and a half inches behind the premaxillary suture. The width of the nasals beneath the horn-core is five and a half inches. The length of the squamosal from the quadrate groove to the posterior end is about thirty-six inches, and its greatest width is nineteen inches.

These two skulls were both found by J. B. Hatcher, in the Ceratops beds of Converse County, Wyoming.

Yale Museum, New Haven, Conn., June 15, 1898.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On the Vapor Pressure of reciprocally soluble Liquids.*—It has been pointed out by OSTWALD that the question whether two liquids are completely miscible with each other or only partially so miscible is in general a question of temperature. Since all vapors are completely miscible at all points above the critical temperature, evidently liquids must be completely miscible at this temperature. Below this temperature, however, a separation may occur. In 1891 Masson showed that there is a temperature at which this separation first occurs and which he called the "critical solution temperature." At this particular temperature the two saturated solutions formed by the liquids have the same composition and the same vapor pressure, and therefore give vapors having identical composition. At this point, consequently, the composition of the liquid must be the same as that of the vapor which is given off on boiling. Below this point, the composition of the distillate obtained from a mixture of two partially miscible liquids, may be considered, according to the author, as also that of a liquid mixture having, if homogeneous, the same composition as its vapor.—*Ann. Phys. Chem.*, II, lxiii, 336–341, December, 1897.

G. F. B.

2. *On Electric Energy by Atmospheric Action.*—An electric generator has been devised by WARREN whose energy comes from direct atmospheric oxidation. Plates of a special porous compressed graphite are prepared, and about a fourth of each plate is made active by immersion in platinic oxalate, drying and igniting in an atmosphere of hydrogen. When placed in contact with a ferrous sulphate solution, oxidation of the iron by the oxygen of the air is effected through the agency of the platinum. The circular lead beam to which these plates are attached surrounds a porous diaphragm containing as the negative element a rod of amalgamated zinc, the carbon plates being arranged so as to allow the platinized portion to project above the solution, consisting of strongly acidified ferric sulphate. On completing the circuit a strong current is produced, which continues until the complete reduction of the ferric salt has taken place, when the action ceases. On withdrawing the zinc, the platinum surface condenses the atmospheric oxygen and so steadily re-oxidizes the ferrous salt, thus renewing the action.—*Chem. News*, lxxvi, 200, October, 1897. G. F. B.

3. *On the Significance of Ionic Reactions in Electrochemistry.*—In a recent lecture on the bearing of the ionic hypothesis on analytical chemistry, KÜSTER made some interesting experiments. The electric exchange $Cu^{++} + Fe = Cu + Fe^{++}$ was shown by placing pieces of iron near the top and of copper near the bottom, of a solution of sodium sulphate; on adding a few crystals of copper sulphate near the copper, a current flows at once from the copper to the

iron through the external circuit. If two iron plates be used in a solution of common salt, a little ferric chloride being placed near the lower one, the change produced illustrates the equation $Fe_2^{+++} + Fe = Fe_3^{++}$. In the case of the reversible reaction $Fe^{++} + I = Fe^{+++} + I^-$, the electrical exchanges were shown by means of two platinum electrodes standing in small crystallizing dishes placed within a larger dish, the latter being filled with a solution of potassium chloride. In one of the small dishes is contained some iodine and in the other ferrous chloride solution. Under these conditions the current in the external circuit flows from the iodine to the strong ferrous solution; but by increasing the concentration of the iodine ions or of the ferric ions, the reaction is reversed and with it the direction of the current. In a similar way the exchange $I^- + Br = Br^+ + I$ was shown. When electrodes of iron and platinum are immersed in a potassium chloride solution and a little iodine is added near the platinum, the current developed corresponds to the reaction $Fe + I_2 = Fe^{++} = I_2^-$. Again a saturated solution of hydrogen chloride in toluene does not conduct electricity even under a pressure of 72 volts; nor does such a solution act on calcium carbonate. But the addition of a little water enables it to accomplish both these results. A saturated solution (0·1 normal) of carbonic acid colors methyl orange less intensely red than a 0·01 normal solution of acetic acid, owing to their dissociation difference. By adding a trace of hydrogen sodium carbonate to the carbonic acid, the diminution of dissociation produced by increasing the concentration of one ion is shown by the disappearance of the red color. The same result follows the addition of sodium acetate to the acetic acid solution; though no change of color is produced when sodium chloride is added to a weak solution of hydrogen chloride colored by methyl orange. A similar phenomenon is the precipitation of lead chloride from its saturated solution by adding a solution of common salt. In the next place, if copper be present in the form of cation in a solution of copper suphate, or in that of a complex anion in Fehling's solution, this fact may be proved by passing a current through two U-tubes, in one of which is a solution of copper sulphate having one of sodium sulphate floating upon it, while in the other is the Fehling's solution and on it an alkaline solution of Rochelle salt. In the one tube the blue zone moves in the same direction as, and in the other in the opposite direction to, that of the current. The absence of cupric ions from Fehling's solution was further shown by means of a galvanic cell containing lead and copper immersed respectively in solutions of lead acetate and copper sulphate. Under these conditions, lead dissolves and copper is thrown down; but both the reaction and the direction of the current are reversed if an alkaline solution of Rochelle salt is added to the cupric sulphate solution.—*Zeitschr. Electrochem*, iv, 105–113, August, 1897. G. F. B.

4. *On the Photoelectric Properties of Certain Colored*

Salts.—Some years ago, Goldstein showed that many salts became colored under the influence of the kathode discharge, and that the salts so colored possessed the property of losing negative electrification readily when subjected to the influence of bright light. More recently, Giesel* has obtained a similar coloration by subjecting the salts to the action of sodium or potassium vapor. ELSTER and GEITEL have now shown that the salts colored by Giesel's method also show the photoelectric peculiarity observed in those colored by the kathode discharge. They have also noticed it in the case of some naturally colored specimens of rock salt. Hence it would appear probable that the coloration is due to a dilute solution of the metal in the solid salt, even though no indications of alkalinity in solutions of these colored salts were found by Abegg. There appears to be no evidence in support of Kreutz's view that the presence of iron salts is the cause of the coloration.—*Ann. Phys. Chem.*, II, lxii, 599–602, November, 1897.
G. F. B.

5. *On Combustion in Rarefied Air.*—Experiments have been made by BENEDICENTI upon the combustion taking place in a lamp fed with olive oil burned under various atmospheric pressure, with the object of elucidating the question of combustion at high altitudes. He finds that combustion is just as complete under 360^{mm} pressure, corresponding to an altitude of 6000 meters, as at ordinary pressures, the only difference being that the speed of combustion is less at the lower pressure. Moreover no appreciable increase occurs in the quantity of carbon monoxide produced as the pressure diminishes.—*Real. Accad. Linc.*, V, v, i, 40, 1896; *J. Chem. Soc.*, lxxiv, ii, 215, May, 1898. G. F. B.

6. *On Molecular Masses of Solid Substances.*—On comparing the densities of a number of solid organic substances, TRAUBE has been able to show that the volume of the group CH_2 is practically the same in solid as in liquid compounds. If we assume that this holds good also for the atomic volumes of the elements, it becomes possible to calculate the co-volumes for a number of solid substances. This done, the result appears that the co-volume forthe solid state appears to have about half the value which it possesses for liquids. But since a diminution of the co-volume on solidification can be due only to the association of molecules, it is assumed by the author that the co-volume in the solid state is in reality equal to that for the liquid state, Avogadro's law holding for the solid state. From this he is able to calculate the association factor for the compounds referred to, and finds that it is roughly equal to 2; all these compounds, therefore, in the solid form being bi-molecular. This conclusion appears to be confirmed by a comparison of a number of inactive racemic compounds, which are undoubtedly bi-molecular, with the corresponding active components. Since these latter are found to have the same co-volumes, they also must be bi-molecular. Applying to inorganic salts the same method, it follows that those

* See this Journal, IV, iv, 152, August, 1897.

which yield two ions are bi-molecular whereas those which yield three ions are monomolecular. Küster's experiments on naphthol and naphthalene are quoted by the author in support of his views, as also the fact that many solid compounds have vapor densities at low temperatures corresponding to a molecular mass double that which they possess at high temperatures.—*Ber. Berl. Chem. Ges.*, xxxi, 130–137, February, 1898. G. F. B.

7. *On the Liquefaction of Hydrogen.*—On the 10th of May, at the Royal Institution, DEWAR succeeded in effecting the complete liquefaction of hydrogen. As early as 1896, he had successfully produced a jet of hydrogen containing liquid, by means of which he was able to cool bodies below any temperature that could be produced by liquid air. It was resolved therefore to construct a larger apparatus of the same type, and the first experiments with it were made on the above date. In his paper read to the Royal Society on May 12th he says: "On May 10th, a start was made with hydrogen cooled to $-205°$C and under a pressure of 180 atmospheres escaping continuously from the nozzle of a coil of pipe at the rate of about 10 to 15 cubic feet per minute in a vacuum vessel double silvered and of special construction, all surrounded with a space kept below $-200°$C. Liquid hydrogen commenced to drop from this vacuum vessel into another doubly isolated by being surrounded with a third vacuum vessel. In about five minutes, 20^{cc} of liquid hydrogen were collected, when the hydrogen jet froze up from the solidification of air in the pipes. The yield of liquid was about one per cent of the gas. The hydrogen in the liquid condition is clear and colorless, showing no absorption spectrum, and the meniscus is as well defined as in the case of liquid air. The liquid must have a relatively high refractive index and dispersion and the density must also be in excess of the theoretical density, viz., 0·18 to 0·12, which we deduce respectively from the atomic volume of organic compounds and the limiting density found by Amagat for hydrogen gas under infinite compression." . . . "Not having arrangements at hand to determine the boiling point, two experiments were made to prove the excessively low temperature of the boiling fluid. In the first place, when a long piece of glass tubing sealed at one end and open to the air at the other was cooled by immersing the closed end in the liquid hydrogen, the tube immediately filled where it was cooled with solid air. The second experiment was made with a tube containing helium." . . . "Having a specimen of helium which had been extracted from Bath gas sealed up in a bulb with a narrow tube attached, the latter was placed in liquid hydrogen, when a distinct liquid was seen to condense. From this result it would appear that there cannot be any great difference in the boiling points of helium and hydrogen." Although Olszewski has published an account of experiments in which hydrogen was obtained in a state of momentary or "dynamical" liquefaction, as a thin mist, in which state some of its constants were measured, Dewar's result, in which the hydrogen was produced as a "static"

liquid with a clearly defined meniscus, must be regarded as an achievement of a greatly higher order.—*Nature,* lviii, 55–57, May 18th, 1898; *Phil. Mag.*, V, xlv, 543, June, 1898. G. F. B.

8. *Some New Methods for the Measurement of Self-Inductance, Mutual Inductance and Capacity;* by H. A. ROWLAND and T. D. PENNIMAN. (From the Johns Hopkins University Circulars, No. 135, June, 1898.)—In the American Journal of Science, December, 1897, and in Phil. Mag., January, 1898, one of us published an account of a large number of new methods for the measurement and comparison of self-inductance, mutual inductance and capacity. Several of these methods have been tested in the Physical Laboratory of the University with great success, notably the methods for the *comparison* of the above quantities.

The methods involve the use of the electrodynamometer with an alternating current, and depend on one general principle—that is, that the deflection of the hanging coil of an electrodynamometer, if the hanging coil and the fixed coils of the electrodynamometer are originally at right angles, is proportional to the product of the currents in the hanging coil and the fixed coils, together with the cosine of the phase difference of the two currents. The dependence of the deflection on the cosine of the phase difference of the currents divides the methods into two general classes—methods in which there is a deflection, i. e., the cosine of the phase difference has a value; and methods of zero deflection, i. e., the cosine of the phase difference is equal to zero. The first class of methods gives the self-inductance or capacity in terms of resistance and b, i. e., 2π (the number of complete alternations per second of the current). These methods were very easy of application; the chief difficulty was the variation of b, as the current was generated in the power house of the University, where the engine was subject to great change of load. The presence of electric absorption also interfered with the accurate determination of the capacity of condensers.

The following method is an example of this class, and of the accuracy with which self-inductance can be determined even under these conditions. In this method the fixed coils of the electrodynamometer are in the main line or circuit, and the hanging coil is shunted off the main circuit around a small resistance, r. In the hanging-coil circuit is placed a non-inductive resistance, R, with a self-inductance, L, under which condition the hanging coil will have a certain deflection when the current is flowing. They, R and L, are now removed, and a non-inductive resistance, R^1, is substituted, which is adjusted to give the same deflection as when R and L were in circuit. Under these conditions,

$$b^2 L^2 = (R^1 - R)(R + r).$$

By this method and similar methods given in the article cited, values of self-inductance were determined that agreed among themselves to within about 1 part in 100, i. e., the determinations were made with about the same degree of accuracy as b could be

determined, on which quantity they directly depended. Taking into account absorption, capacity can be determined by the same method with about the same degree of accuracy. This method is easy to use, as it requires but one adjustment, R^1.

The methods for the comparison of the above quantities gave much more accurate results, as they are independent of the period of the current, the great cause of error in the measurement of the quantities. When care was taken to guard against all inductive and electrostatic action of the different parts of the apparatus on each other, the results derived by the different methods tried were remarkably good, notably the results obtained by the method for the comparison of two self-inductances. The connections for this method are made in this manner :

Let there be two coils of self-inductances, B_1 and B_2 placed together, and let the circuit pass through the coil B_2. From the main circuit, after it has passed through the coil B_2, the hanging coil of the electrodynamometer, having in circuit a self-inductance, L, and a resistance, R, is shunted around a small resistance, r. The coil B_1 is placed in circuit with the fixed coils of the electrodynamometer and a resistance, R^{11}.

The condition, then, for zero deflection when the current is flowing is

$$\frac{L}{B_1} = \frac{R+r}{R^{11}}$$

Using this method and taking B_1 as a standard equal to 1 Henry, several coils were compared with B_1, both singly and in series. To show with what accuracy self-inductances of different amounts can be compared, a few values are given for two periods. The coils being compared with B_1 as a standard.

	$n = 40$		$n = 133$		
Coils.	Results found by direct measurement.	Sums and differences of direct measurement.	Results found by direct measurem't.	Sums and differences of direct measurem't.	Sums and differences.
P_1	·5664	·5663	·5653	·5648	$(C+P_1)-C=P_1$
C	1·3050	1·3049	1·3034	1·3029	$(C+P_1)-P_1=C$
$C+P_1$	1·8713	1·8714	1·8682	1·8677	$C+P_1$

These are good cases of agreement, and show the accuracy of the method for the comparison of self-inductance of different amounts, when care is taken to eliminate heating and electrostatic action of the resistance and leads.

It will be noticed that the value of the self-inductance for the two periods is different; this was due to the electrostatic action of the turns of the coils on each other, and therefore could not be avoided.

When equal self-inductances are to be compared, the accuracy

depends only on the sensitiveness of the instrument to changes in $R+r$; and in the arrangement used in our experiments, the electrodynamometer was sensitive to changes of about 1 part in 10,000 in $R+r$. Therefore the construction of standard self-inductances that will agree with each other to within 1 part in 10,000 is feasible by this method.

9. *Some Notes on the Zeeman Effect*; by J. S. AMES, R. F. EARHART and H. M. REESE. (From the Johns Hopkins University Circulars, No. 135.)—In our investigation of the effect of the magnetic field on radiations in the ether, we have been led to study certain variations from the phenomena discovered by Zeeman, which seem to be worthy of note. Up to the present we have studied the effect of a magnetic field upon the spark-spectra of magnesium, iron, cadmium and zinc. The research is by no means complete, but having discovered several new effects we think it well to publish them at present, and to defer until later a full discussion of the phenomena.

Our apparatus has been the small concave grating of the Physical Laboratory, which has a radius of curvature of about eleven feet. The grating is ruled with 15,000 lines to the inch and is five inches in width. The magnetic field has been produced by an ordinary form of electro-magnet, but we have made no attempt to measure the intensity of the field, because our object has not been to establish numerial relations. The field, however, was strong enough to produce a separation in the case of iron of about a tenth of an Ångström unit, and the definition has been most satisfactory. The method of use was to introduce between the spark and the slit a Nicol's prism and quartz lens, and to photograph the resulting spectra along the middle of the photographic plate, then turning the Nicol's prism through 90°, and at the same time turning a shutter which is placed in front of the photographic plate, to expose the two edges of the plate to the new radiation coming through the Nicol's prism. By this method we secure on the same plate the components of the vibrations polarized along the lines of force and at right angles to them.

We have studied the effect of the magnetic field upon the iron spectrum from wave-length 3400 tenth meters to wave-length 4300, and in this region have noticed that all the lines, with certain exceptions to be noted, are influenced in the way discovered by Zeeman. In particular, when the radiation at right angles to the magnetic field is studied, each line in the spectrum is broken up into three, the central component being plane polarized, with its vibrations along the lines of force; the two side components being plane polarized at right angles to this, their vibrations being at right angles to the field of force.

We have observed, however, that three lines, of wave-length 3587·13, 3733·47 and 3865·67, are affected in the opposite way; that is, the line is a triplet when viewed at right angles to the magnetic field, but the central component is so polarized that its vibrations are at right angles to the field, and the two side components have their vibrations along the field.

Four lines, at 3746·06, 3767·34, 3850·12, 3888·67, have, so far as our indications go, no modification produced whatever. The lines at 3722·72 and 3872·64 are so modified as to be quadruplets, the central component which has its vibrations along the line of force being a close double. There are several other lines concerning which we have doubt, but most of the others examined are clearly modified in the way described by Zeeman. We have noted too that the separation of the side components of the triplets seems to be most irregular; lines whose wave-lengths differ by only a few Ångström units have displacements which differ by 20 per cent at least. In short, there seems to be no regularity in the separations produced. (Several of the above effects have been observed by other investigators.)

In studying the spectrum of cadmium we have observed that the lines at 4678·37, 4800·09, 5086·06, which belong to the "second subsidiary series," and the lines at 3467·76 and 3613·04 which belong to the "first subsidiary series," are all modified in the normal manner; that is to say, in the manner described by Zeeman, and by amounts which are no greater than for iron, but that there seems to be no regularity in the separations produced, either between the two series or between the lines of any one series.

We have been unable to extend our investigations into the extreme ultra violet owing to the fact that the Nicol's prism which we used in order to separate the components, absorbs the waves beyond 3400.

In the study of the spectra of zinc and of magnesium, we have not yet obtained results which are worthy of note.

10. *An Elementary Course of Physics.* Edited by Rev. J. C. P. Aldous, M.A. 862 pp. London and New York, 1898. (Britannia Series: The Macmillan Co.)—In this volume, the chapters devoted to Mechanics, Properties of Matter, Hydrostatics, and Heat have been prepared by the editor; those on Wave Motion, Sound, and Light, by W. D. Eggar; and those on Magnetism and Electricity by F. R. Barrell. The authors have certainly succeeded in giving a very satisfactory and attractive presentation of the subject of physics from the elementary and somewhat popular side. In many cases the subjects are introduced with a brief allusion to the historical development which is sure to make the matter more real to the student. Thus the opening paragraphs devoted to motion begin with the mention of Newton's observation of the falling apple; even a picture of the philosopher is added (perhaps unnecessarily, in this case). The principles are stated throughout in clear and simple language, and the frequent illustrations, verbal and pictorial, are much to be commended; the latter have been for the most part freshly prepared for this volume. Mathematical expressions are largely avoided, which fact, while limiting the usefulness of the book in certain obvious directions, makes it all the more readable for the class of students for whom it has been prepared.

11. *The Storage Battery.* A Practical Treatise on the Construction, Theory, and Use of Secondary Batteries; by AUGUSTUS TREADWELL, Jr., E.E. 257 pp. New York and London, 1898. (The Macmillan Co.)—The subject of storage batteries is one that has always been of great general interest, both from the theoretical and practical standpoints, ever since the earliest attempts in this direction. The present practical treatise is particularly acceptable because it is at once fresh and sufficiently thorough and scientific. Brief accounts are given of the many different forms of accumulators, and these are accompanied by numerous illustrations; those showing the discharge curves are especially valuable. The chemical theory, as now accepted, is explained, and an interesting chapter is devoted to a description of practical storage battery installations at many different points with data as to their practical working. The concluding chapter contains valuable suggestions as to the precautions to be observed in the use of accumulators and the conditions under which they give the best results.

II. GEOLOGY AND NATURAL HISTORY.

1. *Important Vertebrate Fossils for the National Museum.*—Prof. O. C. MARSH has recently transmitted from New Haven to the Director of the U. S. Geological Survey the fourth large instalment of Vertebrate Fossils secured in the West, in 1882–92, under his direction, as Paleontologist of the U. S. Geological Survey in charge of Vertebrate Paleontology. The collection is packed in one hundred (100) boxes, and weighs over thirteen (13) tons. In accordance with law, the material will be deposited in the National Museum. This collection includes twelve skulls and other remains of the gigantic *Ceratopsia* from the Cretaceous; various *Dinocerata* fossils from the Eocene; a series of rare specimens of *Brontotherium*, *Elotherium*, *Miohippus*, and other genera, from the Miocene; a very extensive collection of Rhinoceros and other mammals from the Pliocene; as well as various interesting fossils from more recent deposits.

The other important collections of Vertebrate Fossils secured by Prof. Marsh in the West for the Geological Survey, and previously transferred to the National Museum, may be briefly enumerated as follows:—

(1) Seventy-two (72) large boxes of Pliocene fossils, weighing about 7,500 lbs., were transferred December 31, 1886, and were stored in the Armory, February 8, 1887. The record of these boxes is on file in the office of the Geological Survey, and the Smithsonian numbers of the boxes are 6601–6672.

(2) Thirty-three (33) large boxes (weighing 6,960 lbs.) of rare Vertebrate Fossils, ready for exhibition, were transferred July 17, 1891, and were placed in a case specially prepared for them in the National Museum, before the opening of

the International Congress of Geologists held in Washington that year.

(3) Forty-three (43) large boxes (weighing 4,380 lbs.) of Pliocene Vertebrate Fossils were transferred April 17, 1896.

These various collections with other smaller consignments transferred to the National Museum (255 boxes in all, with a total weight of over 20 tons) were secured under the special direction of Prof. Marsh, as Paleontologist of the U. S. Geological Survey in charge of Vertebrate Paleontology, during 1882–92. The remaining collections thus made, and still at New Haven, will be sent to Washington as soon as their scientific investigation now in progress is completed.

2. *U. S. Geological Survey.*—A new publication of the U. S. Geological Survey has appeared as Folio 1 of the Topographic Atlas. It embraces ten maps selected to illustrate topographic forms described in an accompanying text, by Henry Gannett, and is intended for use in teaching Geography. The topographic types illustrated are:

A Region in Youth (Fargo, North Dakota), *Maturity* (Charleston, West Virginia), *Old Age* (Caldwell, Kansas), *Rejuvenated* (Palmyra, Virginia), also *A Young Volcanic Mountain* (Mount Shasta, California), *Moraines* (Eagle, Wisconsin), *Drumlins* (Sun Prairie, Wisconsin), *River Flood Plains* (Donaldsonville, Louisiana), *A Fiord Coast* (Boothbay, Maine), *A Barrier-Beach Coast* (Atlantic City, New Jersey). These features are illustrated by the sheets noted in parentheses.

3. *The Occurrence of Petroleum in Burma.* Volume xxvii, Part II, of the Memoirs of the Geological Survey of India, consists of a paper of 226 pages, with a large number of folded plates, by Dr. FRITZ NOETLING on the occurrence of petroleum in Burma, and its technical exploitation. This discusses the subject exhaustively, both from the scientific and technical side and further gives an interesting historical summary going back to legendary times. The chief locality is at Yenangyoung, on the left bank of the Irawadi, in the Magwe District, where the petroleum comes chiefly from certain argillaceous beds in the Upper Miocene. Another locality is near the village of Minbu, on the Irawadi, 423 miles above Ragoon; but this has not been exploited thus far to any considerable extent. Some other occurrences are also noted, as that at Yenangyat. It is stated that a peculiarity of the Burma petroleum consists in its large percentage of paraffine wax, which makes it a viscous oil. In consequence of this, at a temperature of 54° F., the petroleum which collects in some pools congeals and forms a greasy matter of the consistency of lard; thus during the winter months the pipe lines cool so much that the flow is seriously clogged. The petroleum contains about 50 per cent of illuminating oil with 40 per cent of lubricating oil and 10 per cent of paraffine wax. The oil from Yenangyat, however, is lighter and contains a larger quantity of illuminating oil than that of Yenangyoung. Previous to 1886 there was no

great variation in the production of oil, but in recent years the amount has run up very largely, and while it amounted to 34,000 barrels in 1886, it has become 257,000 in 1894, although it is remarked that this production is small in comparison to that of Baku or of the United States.

4. *A Text-book of Entomology;* by A. S. PACKARD; pp. xvii + 729, 8vo, 1 pl. and 654 figs. in text. New York, 1898 (The Macmillan Company; $4.50).—This, the latest of Prof. Packard's books on insects, occupies a comparatively new and increasingly important field among modern text-books of entomology. After a brief discussion of the relations of insects to other arthropods and the rest of the animal kingdom, the work is entirely devoted to anatomy, physiology, embryology and metamorphoses. Much the larger portion of the work is given up to the first of the three parts into which it is divided, that on external and internal anatomy, in which some account is given of the physiology of the more important organs, especially those involved in locomotion. The second part, on embryology, follows closely Korschelt and Heider's excellent text-book on the embryology of invertebrates, but the account of the maturation and fertilization of the egg is so brief and imperfect that it gives little idea of these processes. A more noteworthy defect is the apparent omission of any description of asexual reproduction, although the parthenogenetic eggs of *Cecidomyia* are described and figured. The final part, on metamorphoses, is naturally the most interesting part of the book and cannot fail to be of service to the general student of biology. The volume, which is well and profusely illustrated and admirably printed, will be appreciated by every one interested in entomology.

5. *Bibliotheca Zoologica II. Verzeichniss der Schriften über Zoologie welche in den periodischen Werken enthalten und vom Jahre 1861–1880 selbständig erschienen sind.* Bearbeitet von Dr. O. TASCHENBERG. Vierzehnte Lieferung. Signatur 521–560, pp. 4209–4528. Leipzig, 1898 (W. Engelmann).—The editor and publisher of this comprehensive work are to be congratulated upon its near approach to completion. The present Lieferung, No. 14, contains the closing part of the bibliography devoted to the Aves (pp. 4209–4364) and the opening part of the Mammalia (pp. 4365–4528).

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Seestudien:* Erläuterungen zur zweiten Lieferung des Atlas der österreichischen Alpenseen, von DR. EDUARD RICHTER. Geographische Abhandlungen herausgegeben von Prof. Dr. Albrecht Penck. Band vi, Heft 2, pp. 71. Vienna, 1897 (Ed. Hölzel).—The latest contribution to the admirable geographical memoirs edited by Prof. Penck is this paper on the Austrian Alpine Lakes, intended to serve as a text to the atlas which it accompanies. It gives an interesting account of the results of soundings made to

determine the exact form of the lakes, and further, a detailed statement of the observations of the temperature of the water through the different seasons of the year. The change of conditions from the time when the lakes were covered with ice to the warmer period of the summer, and again to their freezing in winter, has been traced out with great minuteness, and the results, while not in all respects novel, contain several points of interest. It is remarked, for example, that the warming of the surface water is accomplished exclusively by the direct radiation and is almost independent of the temperature of the air. The increase in surface temperature may amount to as much as six degrees in a day, though most of that is lost again during the night, particularly in the case of clear weather. At a depth of four meters the effect of the sun's rays may amount to as much as half a degree in a day, while at ten or twelve meters a warming of only one or two degrees in the course of the entire summer is noted; but great differences result according to the purity of the water. It was found, further, that the freezing over begins when the temperature has cooled down to + 1 or + 2, and a temperature of zero degrees before freezing was never observed. It is remarked that further investigations are needed to explain this anomaly. Attention is called in this connection to a paper by Arnet on the freezing of the lakes in Central Switzerland from 1890 to 1896, in which it is stated, in regard to Lake Luzerne, that during freezing and while ice covered the lake, no temperature below 1·25 C. was noted.

2. *Field Columbian Museum.*—The following are recent publications:

Publication 23, Anthropological Series, vol. ii, No. 2. A Bibliography of the Anthropology of Peru; by George A. Dorsey; pp. 57–206.

Publication 25, Botanical Series, vol. i, No. 4. Contribution III to the Coastal and Plain Flora of Yucatan; by Charles Frederick Millspaugh; pp. 345–410.

Publication 26, Zoological Series, vol. i, No. 9. List of a Collection of Shells from the Gulf of Aden, obtained by the Museum's East African Expedition; by Dr. W. H. Dall. D. G. Elliot, Curator of Department; pp. 187–189.

Publication 27, Zoological Series, vol. i, No. 10. Lists of Species of Mammals, principally Rodents, obtained by W. W. Price, Dr. S. E. Meek, G. K. Cherrie, and E. S. Thompson, in the States of Iowa, Wyoming, Montana, Idaho, Nevada, and California, with Descriptions of New Species; by D. G. Elliot; pp. 193–221.

The Pruning Book: A monograph of the Pruning and Draining of Plants as applied to American conditions; by L. H. Bailey; 537 pp. New York, 1898. (The Macmillan Company.)

The Social Mind and Education. By George Edgar Vincent. 155 pp. New York and London, 1897. (The Macmillan Co.)

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[FOURTH SERIES.]

ART. X.—*The Jurassic Formation on the Atlantic Coast.—Supplement*;* by O. C. MARSH.

AT the autumn meeting of the National Academy last year, in New York, I made a communication entitled "The Jurassic Formation on the Atlantic Coast."† In this paper I brought together the results of a careful investigation which I had been conducting for several years, going to prove that the Jurassic formation, generally supposed to be wanting on the Atlantic border, was represented by a definite series of strata in the exact position where such deposits were to be expected. Accompanying this communication, I exhibited a number of drawings and sections illustrating the Jurassic deposits of the West, which I had long before investigated and fully described; namely, the Baptanodon beds, consisting of marine Jurassic strata with many characteristic fossils, mostly invertebrates, and above these the fresh-water Atlantosaurus beds, which have yielded such vast numbers of gigantic reptiles and other characteristic vertebrates. Sections showing the relative position of these deposits, with the strata above and below them as they are seen at several localities in Wyoming and Colorado, were also exhibited.

In comparison with this great development of the Jurassic in the West, I next discussed the so-called Potomac formation in Maryland, in which I had found a corresponding vertebrate fauna that proved the strata containing them to be also of Jurassic age. I then gave a brief account of my researches

* Abstract of communication made to the National Academy of Sciences, Boston meeting, November 18, 1897.

† This Journal, vol. ii, p. 433, December, 1896; and Science, vol. iv, p. 805, December 4, 1896. See also, this Journal, vol. ii, p. 295, October, and p. 375, November, 1896.

during that season, in following essentially the same strata to the eastward through Delaware and New Jersey, and likewise presented evidence showing that apparently the same Jurassic beds were to be found in position beneath Long Island, Block Island, and Martha's Vineyard, represented by the variegated basal clays of these islands, which had previously been supposed to be of much later age. The evidence seemed conclusive that in this series we had remnants of an extensive formation of fresh-water origin, the strata consisting mainly of soft sandstones and plastic clays of great thickness. In their physical characters, and especially in their variegated brilliant colors, these deposits differed widely from any others known on the Atlantic border, and were only equalled in this respect by the Jurassic beds of the Rocky Mountain region. The presence on the Atlantic coast of such an extensive formation, with its massive beds of plastic clay, all of fresh-water origin, clearly proved the former existence of a great barrier between the basin in which these clays were deposited and the Atlantic Ocean, a barrier that has long since disappeared through subsidence, or was broken down by the waves of the Atlantic, which are still rapidly removing the remnants of the formation along its eastern exposure, as may be seen on Block Island, and at Gay Head on Martha's Vineyard.

In discussing the age of this formation, its position above the Triassic and below the marine Cretaceous, its characteristic physical characters, distinct from those above and below, and its western extension into the strata of undoubted Jurassic age in the Potomac beds of Maryland, all pointed to the conclusion that its members belong to the same general epoch, and were deposited during Jurassic time.

In the paper thus cited, I confined myself strictly to the Potomac formation north of the Potomac River, and what I believed to be its eastern extension as far as Martha's Vineyard, all of which I had personally explored. I particularly avoided any discussion of the so-called Potomac beds south of the Potomac River, although I had been over these deposits at various points along the Atlantic border and around the Gulf as far as the Mississippi River. I closed the paper with the promise of taking up that part of the subject later.

As the question was a difficult one and still under investigation, I likewise guarded myself against expressing the opinion that all the so-called Potomac deposits were Jurassic. My words on this point were as follows:

"It cannot, of course, be positively asserted at present that the entire series now known as Potomac is all Jurassic, or represents the whole Jurassic. The Lias appears to be wanting, and some of the upper strata may possibly prove to belong to the Dakota."*

* This Journal, vol. ii, p. 436, 1896.

The Dakota Sandstone.

In regard to the sandstone known as Dakota, and generally considered of Cretaceous age, I also spoke cautiously, as behooves anyone who has seen this formation at many of its outcrops over a wide range of territory in the West, where its physical characters are striking, and its fossil remains are mainly detached leaves of plants.

In figure 1 of my paper, showing geological horizons and designed especially to represent the succession of vertebrate life in the West during Mesozoic and Cenozoic time, and so defined in the text, I left a blank space above the Jurassic for the Dakota, exactly where I had found a sandstone, regarded as Dakota, in place at many widely separated localities. I said little about the Dakota itself, as I did not wish then to raise questions outside the scope of my paper.

Had the occasion been appropriate, I might have said that the group termed Dakota in my section, I consider as more extensive than the single series of sandstones defined as Dakota by Meek and Hayden in 1861. The original locality of this sandstone was the bluffs near the Missouri River in Dakota County, Nebraska, and these authors included with this the supposed southern extension of the sandstone in eastern Kansas. This placed the Dakota on the eastern margin of the great Cretaceous basin which extended westward to the Rocky Mountains. The attempt of Meek and Hayden to identify the Dakota further north, near the mouth of the Judith River, is now known to have failed, but the name transferred to certain sandstones along the flanks of the Rocky Mountains has been accepted, and this term has long been in use for these strata from Canada to Mexico. With this so-called Dakota sandstone, however, have been included other deposits, the upper part of which may be Cretaceous, while the rest I regard as Jurassic, and with good reason. These intermediate beds may be seen at various places, especially around the border of the Black Hills and along the eastern flanks of the Rocky Mountains in Colorado. As I shall refer to this point later in the present communication, I will not discuss it here.

Opinions of Various Geologists.

The paper I have now cited, I regarded as the preliminary statement of an important case, and not its final demonstration. When presented to the Academy, it received the general approval of the members interested in the subject, and one of them, the late Professor Cope, who was best qualified to weigh the evidence of paleontology, fully endorsed my conclusions, and added that he himself had long suspected that the strata under discussion would prove to be of Jurassic age.

When an abstract of my communication was published, although without the main illustrations shown to the Academy, I received further endorsement from geologists familiar with the subject, but from others, marks of disapproval predominated. This I had anticipated in a measure, especially from the paleobotanists, whom I believed responsible for much of the confusion that had so long delayed the solution of similar questions, East and West. This point I brought out in my paper, but in an impersonal manner that I hoped would offend none of the craft.

The prompt and vigorous rejoinders that even my first informal announcement drew from two paleobotanists, A. Hollick and L. F. Ward,* showed that I had trespassed upon their bailiwick, and that some of the questions raised they had settled to their own satisfaction. As their ideas in regard to the value of fragmentary fossil plants as evidence of geologic age differed so widely from my own and from those of many paleontologists, no specific reply on my part seemed necessary, and I have none to make now. Professor Ward has admitted that the plants found with the vertebrates in the Potomac beds of Maryland may be Jurassic, and that removes one of the main points at issue between us. His words are as follows:

"If the stratigraphical relations and the animal remains shall finally require its reference to the Jurassic, the plants do not present any serious obstacle to such reference." (Loc. cit., p. 759.)

That the more eastern beds may represent a somewhat higher horizon, I can readily believe, but I must doubt the evidence that would separate so characteristic and homogeneous a series of sands and plastic clays into two sections, one Cretaceous and the other Jurassic. The few imperfect plant remains that we are told authorize this separation must be reinforced by other testimony to obtain even the support of probability, especially when paleobotanists differ so widely among themselves as to the real significance of the fragmentary remains they describe.

Next in order among my reviewers was R. T. Hill,† well known for his researches in the geology of Texas, but apparently not familiar with the typical Jurassic, East or West. He evidently had not read my paper carefully, though he criticises it at length, mainly to confirm his own conclusions as to the Cretaceous age of certain deposits in Texas, which he seems to imagine I do not endorse. As I especially avoided expressing any opinion on that point, or in regard to the Dakota being the base of the Cretaceous in this country, as I have already stated, no reply at present seems called for on my part, although I hope later to refer to the question he raises about the age of the so-called southern Potomac.

* Science, vol. iv, p. 571, and p. 757, 1896.

† The same volume, p. 918, 1896.

I took it for granted, in my paper cited, that American geologists who were not familiar personally with the great development of the Jurassic formation in Europe, or who had had no opportunity of examining typical sections of this formation in western America, or of seeing its deposits in place full of characteristic fossils and extending hundreds of miles in half a dozen states, were at least sufficiently acquainted with the literature of the last twenty years to know that two of the best-marked Jurassic horizons in any part of the world existed in this country.

Although my communication, as printed, was in fairly clear English, I find it was misunderstood in various other points, as subsequent reviews soon showed. If these marks of disapproval had been recorded by fireside geologists, who so often differ with those who furnish facts, I should have followed my usual rule and made no reply. They were, however, mainly written by field geologists who had seen something of the West, and ought evidently to have seen more, for the facts I stated can be readily verified at any of the localities mentioned and at many others. The failure to do so well illustrates a law of human nature; namely, that men see what they have eyes to see. The West is an extensive country. The plant men who go there seem to see only fossil plants; the invertebrate collectors notice only their own favorites, and as both classes are numerous, the extinct vertebrates are too often overlooked or only peculiar and striking specimens secured. Thus the most valuable evidence as to the age of strata is neglected, and the decision rendered has so frequently to be reversed. This neglect is not confined to field work alone, where fossil vertebrates should be found, but too often extends to the literature of the subject.

Let me illustrate this by a short quotation from a well-known work:

> "The Jurassic system, which is so largely developed in Europe, containing the remains of huge swimming and flying reptiles * * is but sparingly represented in American geology, and none of the gigantic vertebrates have as yet been found here."*

The above extract may fairly be taken as representing the information on the subject known to the authors, or at least to the editor, when this work was published. It is, moreover, a fair sample of much that has since been written about the Jurassic formation of this country and its fossil contents, especially by those not familiar with this subject, but whose work in allied fields should at least have made them acquainted with the main results of our vertebrate paleontology, which had become a part of the world's scientific knowledge.

* Geology of the Black Hills, by Newton and Jenney; edited by G. K. Gilbert, p. 151, 1880.

For example, at the time the above work was published, one of the most fruitful horizons of vertebrate fossils ever discovered had been known for several years in the Jurassic of the West. Many tons of gigantic fossil vertebrates had been collected from several localities, and the principal forms described and figured, while the illustrations had been reproduced even in text-books. Moreover, the Jurassic horizon in which these and other remains were found had been definitely determined and named the Atlantosaurus beds, and a geological section showing their position and characteristic genera had been published several times. The fossils thus discovered embraced mammals, birds, reptiles, and fishes, nearly all of well-marked Jurassic types.

Since 1880, when the statement I have quoted was made, other discoveries have followed in rapid succession, and the Jurassic vertebrate fauna of the West is now known to be a most rich and varied one, far in advance of that from any other part of the world. More than one hundred and fifty species of extinct vertebrates, some of them represented by hundreds of specimens, have been brought to light, and over one hundred of these have already been described, and the more important have been refigured and republished in various parts of the world, including text-books, so that anyone with even an elementary knowledge of the subject can see that they are Jurassic in type. Nevertheless, a number of American geologists whose studies have kept them in other fields still appear to be ignorant of nearly all that has been made known about vertebrate paleontology in this country during the last quarter of a century, and seem to think that the Jurassic formation here is of small importance, and that its area should be restricted rather than enlarged.

Another of my reviewers was G. K. Gilbert, editor of the work from which I have just quoted. Whether he intended his remarks on my paper to be taken seriously is not clear. Apparently he wished to start an academic discussion on correlation, and under the circumstances this would probably have led from the Rocky Mountains to the Mountains of the Moon, one of his latest fields of investigation. If he is really in doubt about the methods of correlation of vertebrate fossils, he can perhaps find the information he needs in text-books.

First of all, however, I must question the accuracy of some of the statements in his review of my paper. One of these is as follows:

"Through a comparison of vertebrates from the Potomac formation with vertebrates from other formations he has inferred the Jurassic age of the Potomac; but he gives no hint of the character of his evidence or the course of his reasoning."*

* Science, vol. iv, p. 876, 1896.

Had this critic read the whole of my paper, he would have found the following statement bearing on this point:

"The Jurassic age of the Atlantosaurus beds of the West has now been demonstrated beyond question by the presence of a rich fauna of mammals, birds, reptiles, and fishes. Among these, the *Sauropoda* were dominant, and the other Dinosaurs well represented.

'In the Potomac beds of Maryland, the same Jurassic vertebrate fauna is present, as shown by the remains of five different orders of reptiles already discovered in them. Among the Dinosaurs are the *Sauropoda*, the *Theropoda*, and the *Predentata*, the first group represented by several genera and a great number of individuals. One of these genera is *Pleurocœlus*, which has also been found in the Jurassic of the West. Besides the Dinosaurs, characteristic remains of *Crocodilia* and *Testudinata* are not uncommon, and various Fishes have been found. The remains of these six groups already known are amply sufficient to determine the age of the formation, and still more important discoveries doubtless await careful exploration."*

Mr. Gilbert's next statement, which is likewise without real foundation, is as follows:

"The conclusion that the Atlantosaurus and other horizons of the Rocky Mountain region are Jurassic was announced in the same way, without citation of evidence."

The announcement of the Atlantosaurus beds as Jurassic was accompanied by a section showing their exact position in the geological scale, and the characteristic genera of Reptilia which then indicated their Jurassic age.† This was followed by descriptions in rapid succession of many other vertebrate fossils, proving beyond question that the horizon was Jurassic. The Baptanodon beds were also defined, and their position in the geological series established by characteristic fossils. The demonstration on this point, I have already given above, and need not repeat here.

Another point needs correction, as Mr. Gilbert evidently consulted my recent classification of the *Dinosauria*‡ without appreciating the evidence it contained. This is shown by the following quotation from his review:

"The closest affinity of the European and American formations seems to be expressed by the statement that there is one American genus which falls in the same family with a European genus."

* This Journal, vol. ii, p. 445, 1896.

† Proceedings American Association, Nashville meeting, p. 220, 1878; see also Popular Science Monthly, p. 520, March, 1878.

‡ The Dinosaurs of North America, 16th Annual Report, U. S. Geological Survey, p. 238, 1896.

The genera named in my recent classification were mainly typical forms, and I had no intention of making a complete catalogue of all the known genera, as anyone familiar with the subject could readily see. By way of further instruction, let me repeat here what I have recently said about one of these typical forms.

"*Pleurocœlus* is one of the most characteristic genera of the Sauropodous *Dinosauria*, and its value in marking a geological horizon should therefore have considerable weight. It is now known from the two European localities mentioned above, both in strata of undoubted Jurassic age. The same genus is well represented in the Potomac deposits of Maryland, and has been found, also, in the Atlantosaurus beds of Wyoming, thus offering, with the associated fossils, strong testimony that the American and European localities are in the same general horizon of the upper Jurassic."*

Had Mr. Gilbert been familiar with the subject discussed in his review, he would have known that, so far as present evidence goes, there are other genera of Dinosaurs common to Europe and America, found in apparently the same Jurassic horizon, and that this is true also of various other reptiles and of fishes. More important still is the correspondence between the genera of Jurassic mammals of the two continents, which in itself is sufficient to demonstrate that they belong in essentially the same horizon.

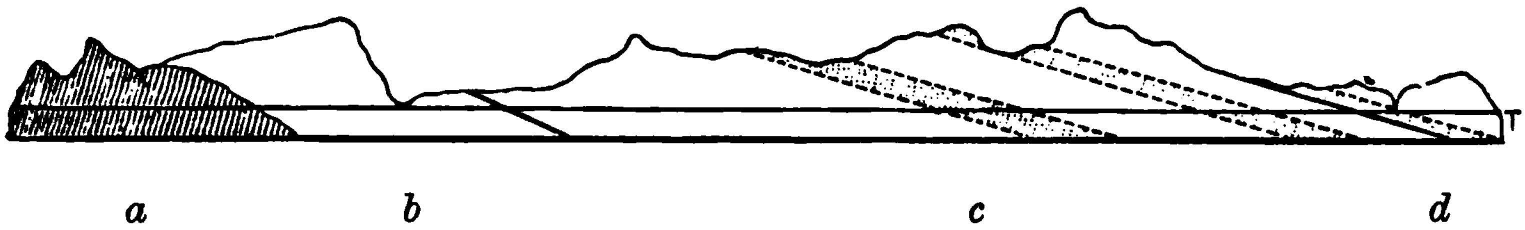
The last point Mr. Gilbert raises in his review is a geological one, and even here he has missed the mark. His words are as follows:

"The physical relations of the beds afford a presumption in favor of their Cretaceous age. Prof. Marsh mentions that the Potomac formation in New Jersey passes by insensible gradation into marine Cretaceous above."

The two statements in this quotation are, in my opinion, both erroneous, and the second is contrary to the idea I intended to convey. The physical relations of the beds in question are in favor of their Jurassic age, and the Potomac strata do not pass by insensible gradation into the marine Cretaceous above. Although the two are apparently conformable, the passage from one to the other was a change from fresh-water to marine deposits, which in itself implies a break that may represent a long period of time, perhaps the entire lower Cretaceous. This break was clearly indicated in the geological section that I gave in my paper (figure 2), and to make this point clear, the same section is here repeated.

* This Journal, vol. iv, p. 415, December, 1897.

This typical section represents the successive Mesozoic and more recent formations, from New Brunswick, New Jersey, on a line southeast, through Lower Squankum to the Atlantic. The distance indicated is about forty miles.



Geological Section in New Jersey.

a, Triassic; *b*, Jurassic; *c*, Cretaceous; *d*, Tertiary; T, tide level.

My explanation was as follows:

"The change from the fresh-water plastic clays of New Jersey to the marine beds containing greensand over them proves not only the breaking down of the eastern barrier which protected the former strata from the Atlantic, but a great subsidence also, since glauconite, as a rule, is only deposited in the deep, still waters of the ocean."*

Since my paper was published, I have been over part of this section several times, and found clear indications of the break itself. Moreover, Professor W. B. Clark, of Baltimore, informs me that he finds distinct unconformity between the marine Cretaceous and the underlying Potomac, along the junction of these two formations, at various other points further south. This fact furnishes a strong argument that the marine Cretaceous belongs to a separate formation from the older fresh-water clays, here regarded as Jurassic.

Another geologist who has written much about the West, but seems to have failed in comprehending the evidence afforded by the vertebrate fossils from well-marked Jurassic horizons, is C. A. White, and as his opinion is frequently quoted, it may be well to correct one of his statements which bears on the question here discussed. In speaking of the Atlantosaurus beds, in 1889, he made this statement:

"If it were not for their dinosaurian faunas their Jurassic age might well be questioned."†

When this statement was made, more than one hundred species of vertebrate fossils besides the Dinosaurs were known from these same Atlantosaurus beds, and among these, the Crocodilians, the Testudinates, and the various smaller reptiles would have been sufficient to demonstrate the Jurassic age of the strata containing them. More important still, several hundred specimens of Jurassic mammals had been found, over a score of species were already described and figured, and these alone were sufficient to prove the horizon Jurassic.

* This Journal, vol. ii, p. 441, 1896.
† Proceedings of the *American Association*, Toronto meeting, p. 213, 1890.

Following these well-known writers, others of less experience in the West have repeated their statements or followed the earlier geologists as to the age of western horizons, and thus tended to continue the confusion where the facts themselves made the whole subject clear. Thus it has come to pass that while the Jurassic formation has been recognized in the Arctic regions of this Continent, and along the Pacific coast, especially through Oregon and California, as well as in Mexico, and likewise in various parts of South America, its development in the Rocky Mountain region has received little attention except from those especially engaged in its investigation. It is not strange, then, that those who have not seen how extensive the Jurassic formation is developed in Europe, and have not examined its characteristic exposures in the West, should fail to recognize it on the Atlantic coast where its features at many points are obscure.

In my paper on this subject last year, I endeavored to show that the burden of proof must rest upon those who denied the existence of the Jurassic formation on the Atlantic border. The evidence against it is still based mainly upon fragmentary fossil plants, in regard to the nature of which the paleobotanists themselves are not in accord.

Cycad Horizons.

I have recorded elsewhere my opinion of the comparative value of different kinds of fossils,—vertebrates, invertebrates, and plants,—as evidence of geological age, and have endeavored to show that plants, as usually preserved and described, are the least valuable witnesses. The evidence of detached fossil leaves and other fragments of foliage that may have been carried hundreds of miles by wind and stream, or swept down to the sea-level from the lofty mountains where they grew, should have but little weight in determining the age of the special strata in which they are imbedded, and failure to recognize this fact has led to many erroneous opinions in regard to geological time. There are, however, fossil plants that are more reliable witnesses as to the period in which they lived. Those found on the spot where they grew, with their most characteristic parts preserved, may furnish important evidence as to their own nature and geological age. Characteristic examples are found among the plants of the Coal Measures, in the Cycads of Mesozoic strata, and in the fossil forests of Tertiary and more recent deposits.

As bearing directly on the question here discussed, the Cycads of the Jurassic period afford instructive examples of the evidence that may be derived from fossil plants under favorable circumstances. The Cycad trunks of the upper Jurassic of England have long been known, and are especially

interesting from the fact that many of them are found imbedded in the original soil in which they grew, thus marking a definite horizon, the age of which has been ascertained by independent testimony.

On the Atlantic border of this country we have a corresponding horizon, determined to be such by its position and by the vertebrate fossils it contains. At various localities in this horizon, especially in Maryland, Cycad trunks have long been known, and within a few years numbers of very perfect specimens have been found under circumstances that serve to fix the horizon in which they occur, and confirm the evidence as to its geological age.

In the Rocky Mountain region, especially around the margin of the Black Hills, a definite horizon likewise exists, in which great numbers of Cycad trunks are found in remarkable preservation. These Cycads resemble most nearly those from Maryland, found in what I term the Pleurocœlus beds of the Potomac formation. In the Black Hills, the age of the horizon has not been accurately determined, but present evidence points to its Jurassic age. The strata here containing these characteristic fossils has long been referred to the Dakota, but, as I have already shown in the present paper, the beds so termed in the Rocky Mountain region are not the equivalents of the original Dakota, and some of them are evidently Jurassic. Until recently the Cycads of the Black Hills, although of great size and remarkable preservation, have not been found actually in place. In the large collection of Cycads belonging to the Yale Museum, a few have been discovered apparently where they grew, and systematic investigation will doubtless show that the various localities where these fossils have been found around the Black Hills are all in one horizon. The evidence now available indicates its Jurassic age, and suggests that it is essentially the same as that of the Cycad beds in Maryland, which I regard as a near equivalent of the well-known Cycad horizon in the Purbeck of England.*

In conclusion, I have only to say that the year which has passed since my first communication to the National Academy on the Jurassic of the Atlantic border has brought no important evidence against the view I then maintained, but much additional testimony in its favor, especially in the region north of the Potomac River that I then discussed. I still hope to return to the subject later, and take up the question of the extension of the same formation along the Atlantic coast further south, and around the gulf border to the southwest, where new evidence is now coming to light.

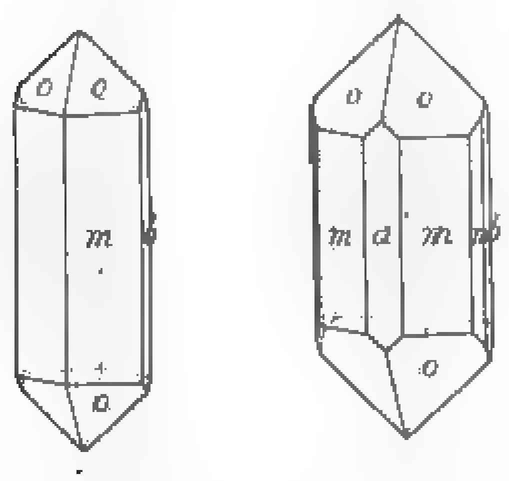
* W. H. Reed, formerly my assistant in the West, informs me that he has found Cycads in the Jurassic of Wyoming, both in the Freeze Out Hills, and also near the Wind River Range. In the former region, they occur about forty feet above the *Baptanodon* beds, so named from a genus discovered by Mr. Reed.

ART. XI.—*Mineralogical Notes*; by C. H. WARREN.

1. *On the occurrence of Melanotekite at Hillsboro, New Mexico, and on the Chemical Composition of Melanotekite and Kentrolite.*

THE rare mineral melanotekite, a basic silicate of ferric iron and lead, was first described in 1880 from Långban, Sweden, by G. Lindström* It was there found as massive material, but crystals of it from Pajsberg, Sweden, have since been described by Nordenskiöld†, who has shown that they are orthorhombic, and similar to kentrolite, a corresponding basic silicate of manganese and lead. The material to be described in the present paper was recently sent to the Mineralogical Laboratory of the Sheffield Scientific School for identification by Mr. W. M. Foote, of Philadelphia, Pa., and later an excellent specimen was received from Mr. J. H. Porter of Denver, Col. Both parties had obtained their material from Mr. Geo. E. Robin of Hillsboro, New Mexico, who had collected it at the Rex and Smuggler mines at Hillsboro, where it is associated with cerussite and a brown, jasper-like, material. The material has a dark brown to almost black color, and gives an ochre-yellow streak, similar to that of limonite or göthite. The specimens consist for the most part of a rather compact mass of crystals, showing distinct forms in numerous cavities. The largest crystals measured about 0·5^{mm} in length, and considerably less in diameter, and showed the simple combinations represented by Figs. 1 and 2. They were always attached, and frequently in such a manner that both ends of the crystal could be observed.

1. 2.



The forms which have been observed are as follows:

a, 100	*m*, 110	*k*, 150
b, 010	*n*, 130	*o*, 111

Usually *m* and *b* are the only faces in the prismatic zone, but the prism *n* was seen on a number of crystals, while *k* was observed only once. The crystals were always terminated by the pyramid *o*. Considerable difficulty was experienced in selecting crystals from which satisfactory measurements could be obtained, as the faces were not only small, but generally vicinal, thus rendering the reflec-

* Öfv. Ak. Stock., xxxv, No. 6, 53, 1880.
† Geol. Fören. Forh., xvi, 151, 1894.

tions somewhat uncertain, and this same difficulty has been experienced by others who have studied crystals of melanotekite. The crystal which was finally selected as best, however, gave excellent reflections from the pyramid faces, and it is believed that the axial ratio derived from the measurements marked with an asterisk in the accompanying table is very nearly correct. The axial ratio is given below, together with those obtained by Nordenskiöld and Flink from melanotekite and kentrolite, from Swedish localities, and by vom Rath from kentrolite from southern Chili.

Melanotekite*	Author	$a : b : c = 0·6338 : 1 : 0·9126$
	Nordenskiöld	$a : b : c = 0·6216 : 1 : 0·9041$
Kentrolite	Flink	$a : b : c = 0·6328 : 1 : 0·8988$
	Nordenskiöld	$a : b : c = 0·6314 : 1 : 0·8793$
	Vom Rath	$a : b : c = 0·6334 : 1 : 0·8830$

The measurements and the calculated values of the melanotekite from Hillsboro are as follows:

		Measured.	Calculated.
$o \wedge o$,	$111 \wedge 1\bar{1}1 =$	55° 00′*	
$o \wedge o$,	$111 \wedge \bar{1}\bar{1}1 =$	119 13 *	
$o \wedge o$,	$111 \wedge \bar{1}11 =$	93 31	93° 32′
$o \wedge m$,	$111 \wedge 110 =$	30 24	30 23½
$o \wedge b$,	$111 \wedge 010 =$	62 32	62 30
$m \wedge m$,	$110 \wedge 1\bar{1}0 =$	64 55½	64 44
$m \wedge n$,	$110 \wedge 130 =$	29 34 to 55	29 53
$m \wedge k$,	$110 \wedge 150 =$	16 52	17 30

The chemical formulas that have been assigned to melanotekite and kentrolite respectively are $Pb_2Fe_2Si_2O_9$ and $Pb_2Mn_2Si_2O_9$, but as the analyses do not agree in a very satisfactory manner among themselves, nor with the theoretical composition, it seemed very desirable to make a new analysis, and some of the very best material was carefully selected for that purpose. The material was treated for a few minutes with a little warm dilute nitric acid to remove a trace of cerussite which could not be avoided, and further than this no visible impurity could be detected. The specific gravity was taken with great care on the chemical balance and found to be 5·854.

The method of analysis was as follows. The mineral was dissolved in hydrochloric acid, and the silica separated in the usual manner. In the filtrate from the silica lead was precipitated as sulphide, and eventually converted into sulphate and weighed. In the filtrate from the lead the iron was precipitated with ammonia, and weighed as oxide. It was subsequently dissolved and determined by potassium permanganate giving a slightly lower result, but the nature of the difference, X, has not been ascertained.

The results of the analyses are as follows:

	I.	II.	Average.	Ratio.		Calculated for $(Fe_4O_3)Pb_3(SiO_4)_3$
SiO_2	15·51	15·48	15·49	·258 or	3·10	15·40
PbO	55·50	55·63	55·56	·249	3·00	57·23
Fe_2O_3 ...	27·49	27·52	27·51	·171	2·06	27·37
X	·83	·81	·82			
H_2O	·68	·67	·68			
			100·06			100·00

The ratio of $SiO_2 : PbO : Fe_2O_3$ corresponds closely to 3 : 3 : 2 and gives as the composition of the mineral, $Fe_4Pb_3Si_3O_{15}$, which may also be written as a basic salt of orthosilicic acid $(Fe_4O_3)\ Pb_3\ (SiO_4)_3$; the radical (Fe_4O_3) being sexivalent, and the one which occurs in limonite $(Fe_4O_3)\ (OH)_6$.

That the analyses of melanotekite and kentrolite, which have previously been made, have failed to yield formulas corresponding to the above, is probably owing to the fact that the material has not been sufficiently pure. A list of these analyses is given below; the liberty having been taken of changing MnO wherever it was found to its equivalent of Mn_2O_3, since it undoubtedly exists in that condition in kentrolite.

	Melanotekite. Lindström. I.	II.	*Kentrolite.* Damour.	Flink.	Calculated for $(Fe_4O_3)Pb_3(SiO_4)_3$.	$(Mn_4O_3)Pb_3(SiO_4)_3$
SiO_2..	17·32	17·22	15·95	17·68	15·40	15·45
PbO .	55·26	58·42	59·79	55·72	57·23	57·43
Fe_2O_3	23·18	22·81	....	5·58	27·37	....
Mn_2O_3	·76	·63	22·26	21·18	....	27·12
X*...	3·59	·84	...	CaO ·91	....	....
					100·00	100·00

Following are the ratios derived from the foregoing analyses:

	SiO_2	:	PbO	:	R_2O_3		SiO_2	:	PbO	:	R_2O_3
Author	·258	:	·249	:	·171	=	3·10	:	3	:	2·06
Lindström I ...	·288	:	·248	:	·148	=	3·51	:	3	:	1·83
Lindström II ..	·286	:	·262	:	·145	=	3·30	:	3	:	1·70
Damour	·265	:	·268	:	·140	=	2·97	:	3	:	1·57
Flink	·294	:	·250	:	·168	=	3·54	:	3	:	2·02

The ratio of $SiO_2 : PbO : R_2O_3$ to correspond to the author's formula should be 3 : 3 : 2, but in all of the earlier analyses except Damour's, the ratio of the silica is a little too high, probably resulting from a slight admixture of quartz or some other silicate, while the ratios of the lead to the sesquioxides in Lindström's and Flink's analyses are nearly 3 : 2. No

*X = CaO, MgO, K_2O, Na_2O, BaO, CuO, FeO, P_2O_5 and Cl.

satisfactory explanation, however, can be given for the low sesquioxides in Damour's analyses. The formulas which have previously been assigned to these minerals are $Fe_2Pb_2Si_2O_9$ and $Mn_2Pb_2Si_2O_9$, respectively, with the ratio of $SiO_2 : PbO : R_2O_3 = 2:2:1$, and, with the exception of Damour's analyses, it will be seen from the following table of ratios that the agreement is not very satisfactory.

	SiO_2	:	PbO	:	R_2O_3.
Author	2·06	:	2	:	1·37
Lindström I	2·34	:	2	:	1·22
Lindström II	2·18	:	2	:	1·10
Damour	1·98	:	2	:	1·00
Flink	2·36	:	2	:	1·27

From the foregoing it may be seen that the analyses thus far have shown a considerable variation, and with the exception of Damour's analyses of kentrolite, they agree better with the author's formula than with the one that has previously been accepted. The author's formula for melanotekite $(Fe_4O_3)\,Pb_3\,(SiO_4)_3$, is substantiated not alone by the analyses of the mineral from Hillsboro, but it corresponds to a type of basic silicate formula, which is quite common among minerals, namely, three molecules of orthosilicic acid in which six hydrogens are replaced by the sexivalent basic radical $(Fe_4O_3)^{IV}$, and six by three atoms of lead. Moreover, if the formula for melanotekite is correct, the formula of kentrolite must be similar $(Mn_4O_3)\,Pb_3\,(SiO_4)_3$, for the two minerals have almost identical crystallographic relations.

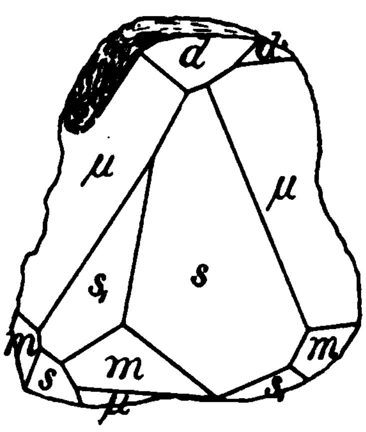
2. *Pseudomorphs after Phenacite, from Greenwood, Maine.*

The pseudomorphs, which are to be described, were discovered by Mr. G. L. Noyes, of Norway, Maine, at a ledge in the town of Greenwood, and were sent to this laboratory for identification. The crystals are remarkable for their size, and are evidently pseudomorphs, as the faces are rough, in places pitted, and in the depressions perfectly developed quartz crystals are visible. A thin section, when examined under the microscope, showed that the material consisted of quartz and a mineral with a foliated or mica-like structure. The color of the crystals is white with a slight greenish cast. It is evident that the crystals were originally attached, and they had been broken from the matrix, so that they thus presented only a portion of the crystal faces, and although the habit differs from that of phenacites which have been described, the characteristic forms and the peculiar symmetry of the crystals render it almost certain that they must be pseudomorphs after that rare mineral. The following forms were observed:

m, $10\bar{1}0$	μ, $02\bar{2}1$	s_1, $3\bar{1}\bar{2}1$
d, $01\bar{1}2$	*s*, $21\bar{3}1$	

The development of the faces is shown in Fig. 3, which represents the smaller crystal weighing 2 lbs., and measuring 4½ inches in diameter, and Fig. 4, representing a crystal 12 inches in diameter, and weighing 28 lbs. If the faces had been symmetrically developed in about the proportions represented by these two partial crystals, the complete form would appear like

3



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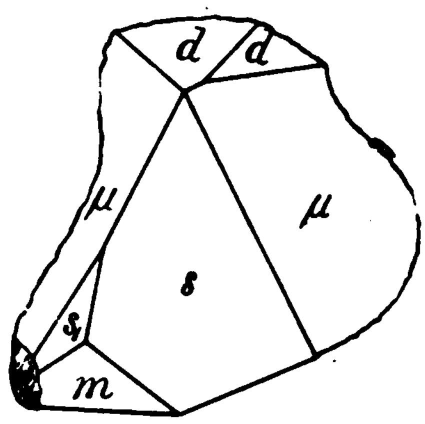

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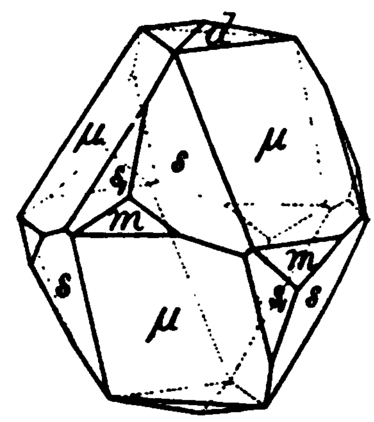

Fig. 5, which differs from previously described crystals of phenacite, in that the μ, *s* and s_1 faces are unusually prominent, while, when prismatic forms are developed, generally the prism of the second order *a* is prominent instead of *m*.

Owing to the rough character of the faces, only approximate measurements could be made with the contact goniometer, and these are given in the accompanying table, together with the values calculated from the measurements of Koksharov*

		Measured.	Calculated.
$m \wedge m$,	$10\bar{1}0 \wedge 01\bar{1}0 =$	60°	60°
$d \wedge d$,	$01\bar{1}2 \wedge 1\bar{1}02 =$	36	35 58½′
$m \wedge \mu$,	$01\bar{1}0 \wedge 02\bar{2}1 =$	33	33 14
$m \wedge \mu$,	$10\bar{1}0 \wedge 02\bar{2}1 =$	66	65 16½
$\mu \wedge \mu$,	$02\bar{2}1 \wedge 2\bar{2}01 =$	92	92 50
$m \wedge s$,	$10\bar{1}0 \wedge 21\bar{3}1 =$	33	32 8
$d \wedge s$,	$01\bar{1}2 \wedge 21\bar{3}1 =$	50	48 59
$s \wedge s_1$,	$21\bar{3}1 \wedge 3\bar{1}\bar{2}1 =$	35	34 2

A determination of the bases was made on a portion of material which was decomposed by hydrofluoric and sulphuric acids, and gave the following results:

Al_2O_3	19·30
Fe_2O_3	·54
Li_2O	·68
Na_2O	1·17
K_2O	·67
H_2O	5·53
	27·89
Quartz and combined silica by difference	72·11

* Materialen zur Min. Russland, ii, p. 308, 1857

The high percentage of water and alumina, and low percentages of alkalies, probably indicate the presence of cookeite, which has been observed as a secondary mineral on other specimens from the locality. Careful tests were made for beryllium with negative results.

3. *Supposed Pseudomorphs after Topaz from Greenwood, Maine.*

In connection with the pseudomorphs just described, there occur other pseudomorphs of quartz after a prismatic, and probably an orthorhombic mineral. The crystals are prisms about 4 inches in length, having an angle about like the prism *n*, 110, of topaz, and are terminated by basal planes. It seems most probable that they are pseudomorphs after topaz, but the original material has been wholly removed, and the crystals now present the appearance of a shell of quartz, with the points of innumerable crystals projecting outward, while within they are cavernous, and the sides of the cavities are lined with small quartz crystals, and rounded prominences of cookeite.

4. *Crystallized Tapiolite from Topsham, Maine.*

In a recent article by Brögger* it has been shown that the isomorphous molecules RNb_2O_6 and RTa_2O_6 (R=Fe and Mn) are also *dimorphous*, there being the *orthorhombic* minerals columbite RNb_2O_6 and tantalite RTa_2O_6 and corresponding to them *tetragonal* species mossite and tapiolite. It was moreover shown that the mineral skogbölite from Tammela, Finnland, described by Nordenskiöld† as orthorhombic, is identical with the tapiolite from Tammela, also described by Nordenskiöld,‡ the apparently orthorhombic habit of the skogbölite resulting from a twinning of a tetragonal crystal about a pyramid of the second order 101, and an extension of some of the pyramidal faces into a prismatic form. Crystals of the tetragonal mineral rutile with an apparently orthorhombic habit like that of tapiolite, and due to a similar twinning, have been described by Pirsson § and Miklucho Maclay‖

The tapiolite crystals to be described here are from the feldspar quarries of Topsham, Maine, and the following forms have been observed on them :

a, 100	*e*, 101	*p*, 111
m, 110	s, 201	*x*, 133

* Über den Mossit and über das Krystallsystem des Tantalit (Skögbolit) aus Finnland, Videnskabsselskabets Skrifter, I Mathematisk-natur Klasse, 1897, No. 7. Kristiania.

† Beskr. Finn. Min., 30, 1855.

‡ Öfv. Ak. Stockh., xx, 445, 1863.

§ Am. J. Sc., xli, 249, 1891.

‖ Jb. Min., ii, 88, 1885.

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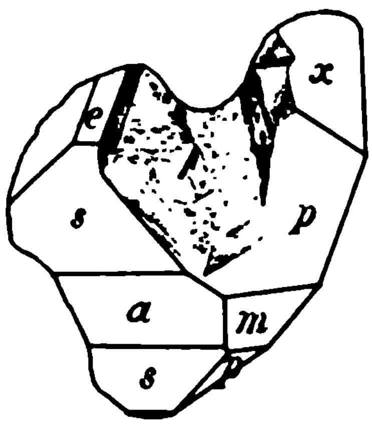

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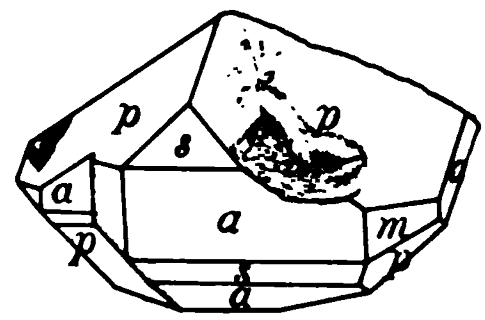

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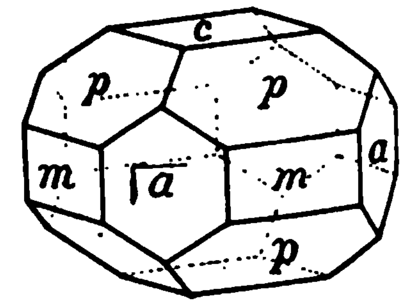


A crystal obtained from Mr. L. B. Merrill of Paris, Maine, and now in the Brush collection at New Haven, has the habit shown in fig. 6. This crystal is apparently not twinned. Its diameter is about 18^{mm} and specific gravity 7·67.

Fig. 7 represents a crystal belonging to Mr. T. F. Lamb of Portland, Me. This crystal is a twin, measuring about 2^{cm} in diameter and having a specific gravity of 7·68. The crystal faces are rough, and they show, when examined with a lens, a superficial growth of minute prismatic crystals in twin position, and crossing at angles of about 60°. The surface of the crystal resembles some of the brookite crystals from Magnet Cove, Arkansas, with a growth of rutile crystals in twin position upon their surface.

Fig. 8 represents a simple and almost ideally symmetrical crystal, about 5^{mm} in diameter and with a specific gravity of 7·87, loaned by Mr. J. S. Towne of Brunswick, Me.

9.

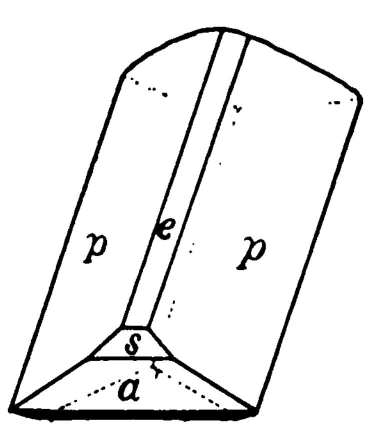


Fig. 9 represents a very symmetrical twin crystal also loaned by Mr. Towne. It has a length of 2^{cm}, a breadth of 1^{cm}, and the specific gravity is 7·66.

The high specific gravity of these tapiolite crystals indicates that they are essentially tantalates and contain very little niobium, as has also been proved by qualitative chemical tests. They contain iron as the base, and give only a very slight reaction for manganese.

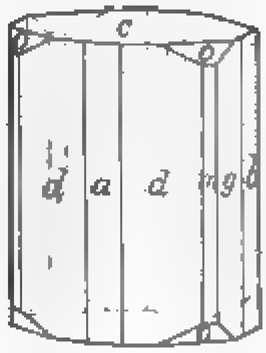
The measurements given in columns I, II and III were obtained from the crystals represented by fig. 6, 8 and 9 respectively, and the calculated values are obtained from the measurement given by Nordenskiöld $p \wedge p$, $111 \wedge \bar{1}\bar{1}1 = 84° 52'$.

	I.	II.	III.	Calculated.
$111 \wedge 1\bar{1}1$	....	....	57° 1′	56° 59½′
$p \wedge p$, over twinning plane,	123° 1½′	122° 59′	....	123 ½
$100 \wedge 111$	61 30½	....	61 28½	61 30
$110 \wedge 111$	47 34	....	47 26½	47 34
$101 \wedge 111$	28 25	28 26½	....	28 29¾
$100 \wedge 301$	27 10	27 12	....	27 29
$111 \wedge 133$	18 3		....	18 14

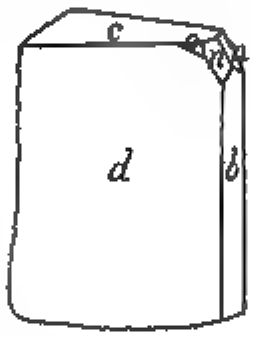
5. *Crystallized Tantalite from Paris, Maine.*

There are also in the Brush collection a few small specimens of tantalite received from Mr. L. K. Stone of Paris, and identified by Prof. Penfield. The specific gravity of the crystals is very high, 7·26, thus indicating that they are tantalite and not columbite. They contain iron, and little or no manganese, which adds to the interest connected with them, since the crystallized tantalite previously described has been of the manganese variety. Only a very little material was found and it is not well adapted for crystallographic study as the faces of the crystals are dull, but sufficiently accurate measurements could be obtained to identify the forms, which were found to correspond to well-known ones on columbite. The habit of one of the crystals is shown in fig. 10, and fig. 11 represents the arrangement of the faces on the corner of another crystal. The forms that were identified were as follows:

10.



11.



a, 100	*c*, 001	*m*, 110	*o*, 111
b, 010	*d*, 730	*g*, 130	*n*, 163

The measured angles are given below, and since the measurements could not be made with sufficient accuracy for establishing an axial ratio for the iron tantalate, they are compared with the angles of columbite, derived from the axial ratio established by E. S. Dana.*

		Measured.	Calculated
$b \wedge g$,	$010 \wedge 130$ =	20° 35′	21° 55′
$b \wedge m$,	$010 \wedge 110$ =	49	50 21
$b \wedge d$,	$010 \wedge 730$ =	70 15	70 27
$b \wedge a$,	$010 \wedge 100$ =	91	90
$b \wedge n$,	$010 \wedge 163$ =	31 15	30 50
$n \wedge n$,	$163 \wedge \bar{1}63$ =	19 30	19 54
$o \wedge o$,	$111 \wedge \bar{1}\bar{1}1$ =	61 30	62 27

6. *Cobaltiferous Smithsonite from Boleo, Lower California.*

This mineral was sent to this laboratory for identification, by Mr. Geo. W. Fiss of Philadelphia, and was supposed to be the rare hydrated cobalt carbonate, remingtonite, the composition of which is not known. The mineral consists of little

* Zs. Kr., xii, 266, 1886.

crystalline particles of a delicate pink color, imbedded in gyp-
sum and associated with a little atacamite. The mineral was first carefully selected from all material of a green color by hand picking, and was then crushed and sifted to a uniform grain, and treated with the heavy solution to separate the lighter portion. The heavy portion when examined under the microscope was apparently very pure. The specific gravity was found to be 3·874, and an analysis gave the following results:

	I.	II.	Average.	Ratio.	
CO_2	36·89	36·99	36·94	·839	·839
FeO	·33	·33	·33	·004	
ZnO	39·03	39·01	39·02	·481	
CoO	10·27	10·24	10·25	·126	·838
MnO	3·40	3·32	3·36	·047	
MgO	7·00	7·43	7·22	·180	
CuO	1·63	1·67	1·65		
Cl	·11	....	·11		
H_2O	1·24	1·34	1·29		
			100·17		

Regarding the small amounts of CuO, H_2O and Cl as impurities, resulting possibly from a slight admixture of atacamite, the ratio of $CO_2:(Zn+Co+Mn+Fe+Mg)O$ is ·839 : ·838 or almost 1 : 1, indicating that the mineral is a normal carbonate and essentially a zinc carbonate, smithsonite, in which the zinc is partially replaced by cobalt, manganese and magnesium.

In conclusion the author desires to express his thanks to those gentlemen, whose names have been mentioned in this paper, for their kindness in placing their specimens at his disposal, and especially to Prof. S. L. Penfield for the valuable advice and assistance which he has rendered during the investigation.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School.

ART. XII.—*The Origin and Significance of Spines: A Study in Evolution;* by CHARLES EMERSON BEECHER.

[Continued from page 20.]

CATEGORIES OF ORIGIN.

As previously shown, spines are formed either by growth or by suppression, and therefore the processes determining their production are either constructive through concrescence or destructive through decrescence. Each of these is in turn determined by forces from without the organism (extrinsic) or by forces from within (intrinsic). In this connection, it is of no especial moment whether or not the intrinsic forces are primary or are an immediate or subsequent reflex from the extrinsic. The main thing is the direction of the dominant force, whether centripetal or centrifugal. If, in some cases, it can be shown that spine development has been accomplished by intrinsic forces in the organism, then this development may be brought about independently of the environment and possibly at variance with it. Also, if in other cases, the extrinsic forces or the influences of the environment have caused spine growth, it may in some instances illustrate the formation and transmission of an acquired character, or at least the operation of organic selection.

The point has now been reached where it is impracticable to make a rigid classification of the direct factors or an exact determination of primary and secondary causes. It was remarked at the beginning of this paper, that single causes were not sufficient in every case to account for spine growth, and while it is comparatively easy to formulate abstract expressions or terms covering all possible cases, it will be found difficult to construe properly certain factors to fit into any particular conception. In illustration of this, the foregoing statements may be taken. Thus, spines are formed by the only means possible, either by growth of new tissue or by decrease in old. Again, the forces must act from the interior or from the exterior; in other words, they must be intrinsic or extrinsic. But in some specific instance, while considering food, forces of nutrition, external or internal demands, reactions, etc., a question may arise as to the proper disposition to make of a spine developing primarily by external stimuli and becoming a defense and secondarily a weapon; yet which by differentiation in time loses some of its protective and offensive qualities, and by selection may be confined to one sex.

Growth and decline are underlain by the processes taking place in individual cells as well as in aggregates of cells, for spine growth must be considered in unicellular as well as multicellular organisms.

Ryder[61] has very philosophically discussed the correlations of volumes and surfaces of organisms, and has reached the conclusion that "the physiological function of a cell is also a function of its figure, i. e., of its morphological character; that is to say, cells tend to elongate in the direction of the exercise of their function." Out of this may be deduced the correlative conclusion that aggregates of cells having a like function also tend to elongate in the direction of the exercise of this function; and, further, it may be asserted that parts or portions of cells will act in the same manner.

A familiar illustration of these principles as applied to a single cell may be taken from the Rhizopod, *Amœba proteus*. When disturbed by incident forces in all directions, it assumes a globular form. Under continuous motion of its own, it is elongated in the axis of motion, its larger pseudopodia being thrust out in more or less the same direction. The presence of a favorable exciting cause, like a particle of food, produces extension of the protoplasm to envelop it.

Furthermore, as is well known, continuous extra-pressure on any part of an organism produces atrophy and absorption, and intermittent or occasional pressure causes hypertrophy and growth. That the pressure should be intermittent, seems a necessary condition for hypertrophy, in order that the parts affected may have normal intervals allowing the active exercise of nutrition.[65] This may be regarded as a parallel statement of the law of disuse and use; the former causing organs or parts to dwindle away and lose their function, and the latter producing increased nutrition and growth.

This ratio of exchange between nutrition and waste is on the side of full or excessive cell-nutrition, producing growth in the parts affected, while deficiency of nutrition produces decline or suppression. If the successive increment constituting growth is along definite progressive lines towards higher structures, and the decrement affects the decline of useless parts or permits of the replacement of a lower by a higher structure, then the sum of the changes is progressive evolution.*

Growth, as stated, seems to require normal intervals for the proper exercise of nutrition, which involves an intermittence of the exciting or stimulating forces. Rhythm has been shown by Spencer[66] to be a necessary characteristic of all motion, and therefore in considering either the intrinsic or

* This is very near Cope's idea of progressive evolution.

extrinsic forces acting on the structures of an organism, they must be rhythmic or intermittent. In the environment, the most apparent changes are those of light and darkness, heat and cold, moisture and dryness, and variations in amount of oxygen, all of which affect an organism directly, and also through the accompanying variations in the character and amount of the food supply, the number of enemies, etc. These and most of the mechanical forces of the environment are therefore intermittent, and their resultant must have a definite tendency, so that the effects are not with each change successively positive and negative to the same degree; that is, the same structures or adjustments are not alternately made and unmade.

It is generally recognized that there is a necessity for a force or energy in living organisms, which is not the immediate and direct result of external agencies, but upon which these fall and produce reactions. It is considered as a phase or kind of vital force directing growth, and therefore a growth force, or the bathmic force of Cope.[10] The internal energy of growth, involving the capacity or effort of responding to external stimuli, is termed entergogenic energy by Hyatt.[34] Without this power, an organism would be unable to move or respond to external stimuli. The effect of the action of this kind of energy must be the resultant between "the structures already existent in the organism and the external forces themselves."[34] Since the growth force is within the organism, or inborn, it is one of the principal characters transmitted through heredity, and if it is in excess of the external forces, the modifications will be principally congenital or phylogenic. If, on the other hand, the external forces predominate, the modifications will be principally adaptive, or ontogenic. In each case, the resultant is the actual visible effect of the two. If both are toward the establishment of similar structures, their effect will be the sum of the two; but if they are opposed to each other, the effect will be their resultant, the nature of which, as seen above, will depend upon their relative power.

These conclusions can be correlated directly with the developmental variations occurring in the life history of any great group of organisms. Anyone who has studied the chronological development or the phylogeny of a class of forms cannot fail to have been impressed with the fact, that all types of life are physiologically more plastic or subject to greater changes near their point of origin. That is, the maximum of generic, family, and ordinal differentiation is found at an early period, while the greatest specific differentiation occurs at a later period. This shows that the results of variation at first affect the

physiological and internal structures, and that later the changes are mainly physical and peripheral.

One explanation of this would be that the forces of the environment are at first freely transmitted and produce internal modifications, and that later these characters become stable, making the effects of the external stimuli apparent in the superficial differentiation of the organisms.

In any event, the modifications in function and structure are followed by modifications in surface, showing that the more important physiological and structural variations are the first to be subjected to heredity and natural selection, which tend to fix or hold them in check. Features of less functional importance, as peripheral characters, are the last to be controlled, and therefore present the greatest diversity, while in this diversity spinosity is the limit of progress. In order to be hereditable, the modifications through the environment must have induced correlative internal adjustments and changed forces which can be transmitted to offspring, and they in turn reproduce the specific modifications.

For the purpose of illustrating these statements, the evolution of the Brachiopods and Trilobites will be taken. The Brachiopods are divided into four orders, all of which appear in the Lower Cambrian and continue to the present time. Schuchert[61] states that "of the 49 families and subfamilies constituting the class, 43 became differentiated in the Paleozoic, and of these 30 disappeared with it"; also, "of the 327 genera now in use, 227 had their origin in Paleozoic seas, or nearly 70 per cent of the entire class." Throughout the Cambrian, "differentiation was mainly of family importance." "Differentiation is most rapid near the base of the older systems, and diminishes the force from the older to the younger geologic divisions." The most rapid increase was in the Ordovician, the culmination was in the Devonian, and the rapid decline came with the Carboniferous. About six thousand species are known, and of these probably not more than one hundred and fifty are living.

Similar data are derived from the Trilobites. This group is found all through the Paleozoic, at the close of which it became extinct. Two of the three orders are found in the Lower Cambrian. The remaining order appeared just after the close of the Cambrian in the early Ordovician, yet through the whole of the remaining sediments not a single new ordinal type was enveloped. When applied to a single order, the same truth comes out. The order Proparia is one whose entire history can be traced, extending from the Ordovician through the Silurian and Devonian. All the families appear in the Ordovician; in fact not a single family type in this or

the other orders was produced during the whole Silurian, Devonian, and Carboniferous.[6]

As the classes, orders, and families are based upon the physiological and important functional structural characters or differences, it is evident that at or near the beginnings of their life history is found the demonstration of the domination of phylogenic over ontogenic characters.

Conditions or forces affecting growth.—Since spines are purely organic structures, their production must follow the general laws of organic change. The forces considered as of most consequence are two: (1) the external stimuli from the environment, and (2) the energy of growth force. These, with their opposites (1*a*) the restraint of the environment, and (2*a*) the deficiency of growth force, are believed to include the chief active and passive causes, not only of spine production, but of growth and decline in general. Correlating these four causes with their constructive and destructive agencies, together with their extrinsic and intrinsic modes of action, as previously explained, there result (A) the external stimuli of the environment as an extrinsic cause of concrescence; (B) energy of growth force as an intrinsic cause of concrescence; (C) external restraint as an extrinsic cause of decrescence; and (D) deficiency of energy of growth force as an intrinsic cause of decrescence. The remaining vital forces (nerve force, or neurism, and thought force, or phrenism) are not primary, and, although doubtless affecting growth in higher organisms, cannot be original causes applicable to all forms of life, both plant and animal.

In tabular form, the divisions and relationships of the factors of spine genesis may be expressed as follows:

Spines originate by	Constructive agencies (concrescence) acting	extrinsically (centripetally)	A from external stimuli
		intrinsically (centrifugally)	B from growth force
	destructive agencies (decrescence) acting	extrinsically (centripetally)	C from external restraint
		intrinsically (centrifugally)	D from deficiency of growth force

Under the last four divisions (A—D), it is proposed to discuss the origin of spines, and from the observations made, to derive certain conclusions regarding the significance of the spinose condition.

A. *External Stimuli.*

Under external stimuli are included all the forces of the environment (chemical, physical, organic, and inorganic) which, through their impact or influence on an organism, produce a consonant favorable change or disturbance. In general, it will be seen that the number of impressions and their power will depend largely upon the position and character of the surface upon which they impinge. The more exposed the position, the greater will be their strength and number, and if these stimuli or impressions are intermittent, and not so violent as to produce waste and rupture, growth will ensue. Under ordinary conditions, exposed parts will naturally be the first to receive sufficient stimulus to produce growth, and there will be normally a direct correlation between growth and stimulus. In a simple diagrammatic form, this would be expressed by a series of lines, the first representing a plane surface. Then, owing to the impossibility of maintaining a uniformly intermittent stimulus or a uniform response, some point or spot on this surface would grow in excess of the others. This difference would be augmented by the more favorable position of the spot to receive stimuli, further growth would take place, the growth force decreasing with the increase of distance, and the final action of these forces, stimulus and growth, would be to produce a pointed elevation. Such structures or outgrowths, especially when made of hard rigid tissue, would be termed spines under the general definition. The spine may be viewed as an attached organism, and its conical habit of growth would then conform to the law of radial symmetry, as determined by the physiological reaction from equal radial exposure to the environment. That all the irregularities of contour in all organisms have not developed into pointed processes or spines is not, therefore, the fault of the simple reciprocity between growth and external stimuli. This kind of development, however, requires a direct and immediate responsive external growth to the exciting force, which from various causes is frequently absent. Obviously, stimuli which result simply in motion or equivalent internal adjustments can have no effect toward spine production, so that only the results of such stimuli as bring about some accompaniment of superficial growth will be considered.

With the exception of perfectly spherical, freely moving forms, all organisms have certain parts which are more exposed to the forces of the environment than others, and from the principles already ennunciated, such exposed parts under normal conditions will grow. This growth in the direction of

function and stimulus, when acted upon by the hereditary functional and structural requirements of the organism, serves to produce the various external organs and appendages. But when the surface upon which the stimuli fall is not thus predetermined by heredity to grow into a certain organ or functional part, there results a normal responsive action between growth and stimulus, which, as already seen, tends to produce a conical or spiniform growth.

Under ordinary favorable conditions, simple external stimuli acting blindly through no agencies of selection would develop spines on all the most exposed parts, and tend to differentiate ornamental features. This has been the case with many organisms and colonial aggregates possessing no power of selection or not acted upon by any forces of determination, conscious or unconscious. In such cases, spines may or may not serve for protection, and their function, if any, can be only determined separately for each case. If, however, the added function of offense is included, it is manifest that the spines must be located in special positions adapted to use for offensive purposes as on the tails of some animals and not necessarily over vulnerable parts. Here the selective agency of special adaptation is shown. Again, if while there is agreement in other essential characters, spines or horns are confined to either sex, it is evidently a case of sexual selection. Further, if they develop in harmony with the environment, or in a manner parallel to similar features of other organisms, it is through the operation of physical selection.

Altogether, under the general forces of external stimuli, there are five aspects in which to consider the production and growth of spines, viz:

A. *From External Stimuli.*

A1.—In response to stimuli from the environment acting on the most exposed parts.

A2.—As extreme results of progressive differentiation of ornaments.

A3.—Secondarily as a means of defense and offense.

A4.—Secondarily from sexual selection.

A5.—Secondarily from mimetic influences.

B. *Growth Force.*

In unicellular organisms, growth force, or bathmetic energy, must reside wholly in the germ cell, and therefore is concerned with reproduction as well as with cell differentiation. In multicellular organisms, the growth force is in both germ and soma cells, and its relative strength seems to depend upon

its power to reproduce lost parts, often including germ cells as well as soma cells. In many of the lower classes, the growth force is able to complete a structure or lost part without the stimulus of use, which in higher animals often seems to be part of the necessary requirements for growth.

Growth itself is the repetition of cells under nutrition and stimulus, and the latter may be hereditary or extra-individual. It is now recognized that since the division of a cell makes two unlike cells, each unlike the parent, such repetition will produce structures which present some degree of difference. The variation is therefore a necessary quality of growth, and its degree will change in response to the differentiation of the forces affecting growth.

When spines which have arisen from intrinsic growth force only are sought, it is apparent that they cannot be distinguished from those arising from external stimuli acting on and directing the growth force, unless, in some instances, they are found to be developed independently or even at variance with the environment. Because spines are sometimes useful to the organism, it is impossible to believe that they have originated from that cause, since their existence in some form must precede the capacity of making them useful. After they began to develop by either intrinsic or extrinsic forces, their being found useful would simply tend to their conservation and further development.

Variation which is not restricted by natural selection or a long line of hereditary tendencies is known as free variation. It is best exhibited in a stock which occupies for a considerable time a region favorable in respect to food, climate, and absence of dominating natural enemies. This relation has been called the period of "Zoic maxima" by Gratacap,[21] and has been further discussed by the same author, under the aspect of numerical intensity.[22] The most rapid rise of a stock is considered to be consequent to a favorable environment and high vitality.

In illustration of these points, the Achatinellæ of the Sandwich Islands afford a good example. The great number of species on these islands has probably been evolved since Tertiary times, and the process of specific delimitation is apparently still going on, for species are now to be found which did not exist fifty years ago (Verrill); also, a few species formerly common are now obsolescent or extinct. According to Hyatt, they all can be deducible from a single species which has differentiated in time through divergence, dispersion, and colonial isolation. In early times, birds may have fed upon them, but the complete or partial extinction of the former by man has resulted in complete immunity for the arboreal Achatinellæ,

and it is now common to find several of the most highly colored varieties feeding together on the same leaf. The modern importation of pigs, sheep, and mice on the islands has introduced an enemy to the terrestrial species, the effects of which are already being noticed. In specific differentiation and in individual variation, both Hyatt and Verrill regard the extraordinary development of this type as characteristic of free variation, under favorable conditions, in a plastic stock which has not yet reached its limits nor become fixed.

Among the Crustacea, the remarkable evolution of the genus *Gammarus* in Lake Baikal,[17] and of *Allorchestes* in Lake Titicaca,[19] seem to furnish parallel examples. *Allorchestes* ranges from Maine to Oregon and southward, through the United States, Mexico, and South America to the Straits of Magellan. Before Lake Titicaca was explored, but one or two authentic freshwater species were known from both continents; yet from this lake basin alone, Faxon[19] has described seven distinct species, constituting the entire Crustacean fauna with the exception of a species of *Cypris*. Several species are "remarkable among the Orchestidæ for their abnormally developed epimeral and tergal spines." These and the species of *Gammarus* from Lake Baikal will be referred to again later in this paper. It is simply desired here to indicate that these variations in *Achatinella* and *Allorchestes* have arisen from a single parent stock, within a small geographic province. The natural interpretation seems to be (*a*) that the environment is favorable, as evinced from the great number of individuals; (*b*) that this has favored and increased the growth force; and (*c*) that, finally, the law of multiplication of effects, reproductive divergence,[67] the survival of the unlike, and the conservative forces of natural selection and heredity have directed the growth force, and produced the specific differentiation which is now found.

A factor of Evolution, called "Reproductive Divergence" by Vernon,[67] seems to be operative here, since it affords an explanation for a means of differentiation in a single stock under a common environment. As this factor has but recently been discussed, it may well be defined at this time, so as to enable a direct application to be made. Reproductive divergence assumes that in many species there will be greater fertility between individuals similar in color, form, or size, than between individuals not agreeing in these respects, and that in subsequent generations, the divergence will become progressively greater in respect to the characteristic in question, so that finally the original stock will become separated into distinct varieties, sub-species, or species.

When, from any cause, the forces of nutrition are directed toward spine production, and when the direct results are accomplished in the reciprocal formation of one or more spines, there is often an apparent inductive influence or impulse given to growth toward the further production or repetition of spines. This may result in the formation of compound spines, or a group of spines, or even produce a generally spinous condition.

Naturally, spines arising through growth force may be useful for defense and offense, and the selective influences of sex and mimicry may also tend to greater development and elaboration. Furthermore, growth forces reacting on any external structures, as lines, lamellæ, ribs, nodes, etc., may tend to differentiate such ornaments into spines.

Therefore, under the general consideration of spines produced through growth force, the following factors are offered for consideration:

B. *From Growth Force.*

B 1.—Prolonged development under conditions favorable for multiplication.

B 2.—By repetition.

B 3.—Progressive differentiation of previous structures.

B 4.—Secondary development through the selective influences of defense, offense, sex, mimicry, and other external demands.

C. *External Restraint.*

Intermittent stimulus, as previously shown, produces growth in the direction of function. When the growth equals the waste, an equilibrium or static condition is reached, and no relative change occurs. The absence of either extrinsic or intrinsic stimulus will not be favorable to growth, and under such conditions, an organ or structure may remain undeveloped, or, if already present in the organism, it may waste away and degenerate into a vestigial structure, or even disappear altogether.

On the other hand, it is well known that continuous pressure not only prevents growth, but in addition resorption takes place, and in this way, the whole or a portion of a structure may be removed. These changes have frequently been studied in embryos, as well as in many internal structures, and are also familiar in the enlarged pedicle openings of many Brachiopods, caused by pressure of the pedicle, and in the similar opening for the byssal plug of *Anomia.* Packard[64] gives examples among the Crustacea and Insects, which are clearly to the point. He says of the Crustacea, "It may here be noted that the results of the hypertrophy and overgrowth of the two

consolidated tergites of the second antennal and mandibular segments of the Decapod Crustacea, by which the carapace has been produced, has resulted in a constant pressure on the dorsal arches of the succeeding five cephalic and five thoracic segments, until as a result we have an atrophy of the dorsal arches of as many as ten segments, these being covered by the carapace."

The restraint of the environment through unfavorable conditions is the antithesis of A, or the influence of constructive external stimuli, and is considered as the extrinsic operation of destructive agencies. It is evident that external unfavorable conditions will repress growth, with a resultant atrophy of the structures affected. In this way, also, the environment may cause the disuse of an organ, which by consequent suppression may dwindle away to a spine, as in the leaves and branches of desert plants, and the spurs of the Python[60] representing the hind limbs. It may likewise repress growth, as in the spines on the lower side of the poriferous coral, *Michelinia favosa*,[40] representing aborted attempts at budding, the failure being due to the unfavorable position of the buds for securing food.

The restraint of the environment may also act in a mechanical manner to produce spines, as will be shown subsequently in some Brachiopods and Trilobites. Furthermore, spines arising through any phase of external restraint, may secondarily come under the influences of natural selection, and be useful for protection and offense, or conform to other external demands.

Under the head of external restraint, therefore, are the following categories:

C. *From External Restraint.*

C 1.—Restraint of environment causing suppression of structures.

C 2.—Mechanical restraint.

C 3.—Disuse.

C 4.—Secondarily for protection, offense, etc.

D. *Deficiency of Growth Force.*

The growth force in organisms may be reduced in several ways, the most general and obvious modes being by an unfavorable environment, lack of physiological plasticity, too close interbreeding, pathologic influences, and parasitism. The first commonly implies a scarcity of food, or it may be that the temperature, moisture, light, elevation, or other conditions are unsuitable to the normal development. The lack of physiological plasticity affects growth force by its resistance to change, and is most strongly apparent in highly specialized forms. The

effects of closé interbreeding in reducing vitality are too well known to require farther notice.

Only in exceptional instances can individual pathologic conditions have any effect on a stock. The retrogressive series of animals which are diseased in appearance, and are considered by Hyatt[34] as akin to pathologic distortions, are apparently types which have ceased to advance physiologically, and are therefore only adapted to special sets of conditions. In these, the pathologic or abnormal condition is racial instead of individual, and its cause seems to be a deficiency of vital power combined with great external differentiation, the final result being the assumption of characters belonging to second childhood and ending in extreme senility, with the loss of spines and other ornaments.

The life history of parasitic organisms shows their origin from higher normal types by a process of retrogression through loss of motion and disuse of parts. Their mode of living implies dependence upon the vitality of an immediate host, and altogether they may be deficient in the energy of growth force.

Any of the preceding factors, single or combined, acting upon an organism or group of organisms will produce suppression of structures or functions. Whether from external or internal causes, the waning and disappearance of characters are almost always inversely to the order of their development or appearance, either in the race or in the individual, and the most primitive or axial characters are therefore the most persistent and the last to disappear. In this way, a leaf may be suppressed into a spine representing the midrib, a branch into a spiniform twig, a leg or digit into a spine, etc. As in other primary causes of spine genesis, there may also come secondary influences of protection, offense, etc., controlled by natural selection.

It will be convenient to consider spine production from lack of growth force under three heads:

D. *Deficiency of Growth Force.*

D 1.—Intrinsic suppression of structures and functions.
D 2.—Disuse.
D 3.—Secondarily for protection, etc.

[To be continued.]

ART. XIII.—*The Prehistoric Fauna of Block Island, as indicated by its Ancient Shell-heaps;* * by G. F. EATON. (With Plates II and III.)

Introduction.

BLOCK Island is well known to New England people, both as a healthful summer resort and as a fishing station of great importance. Its fame, moreover, dates back to the remote years before the coming of the first white men, for the legends narrated to the settlers by the former Indian inhabitants, the Manissees, tell of long-continued wars of conquest waged for the sake of the highly prized fisheries. Little is known of this Manissean colony except that they were originally of the same stock as the warlike Narragansett tribe, and that, at the dawn of New England history, they had already occupied the Island during a period of time so long that they themselves had no idea when their ancestors came. A conquered race, they have passed away with the advance of civilization, until now their very name is almost forgotten. Few records are extant which give any information about the manner of life of these aborigines. What food could they procure upon a bleak storm-swept island, and what were their arts? With a view to obtaining some answer to these interesting questions, careful exploration has been made of the shell-heaps of the Island, and the results of the work are embodied in this paper.

The first scientific notice of the Island appeared in 1840, in the State Geological Report of Rhode Island. Since then many discussions of its geological formations have been published, and chief among recent writers on this subject is Prof. Marsh of Yale University. His papers entitled "The Geology of Block Island" and "The Jurassic Formation on the Atlantic Coast," lately published in this Journal, have done much to remove the stumbling-block long offered by the basal clays of the islands off the New England coast. From the first of these papers (vol. ii, p. 297, 1896) is taken the following quotation, which was apparently the first notice of the Block Island shell-heaps to appear in any scientific publication:

"On some of the glacial hills near the shore, or around the Great Pond, shell-heaps of considerable antiquity may be observed, but so far as I could ascertain, none of them have been explored. One may be seen on the south side of the road recently cut through a low hill near the new steamboat landing on Great Pond. The deposits are several feet in thickness, indicating a long occupancy of the place by some of the early inhabitants of the island. The short examination I was able

* A Thesis presented for the degree of Ph.D. at Yale University, June 1, 1898.

to give this 'kitchen midden' disclosed many marine shells, mainly species now living in the adjacent waters, the most abundant of which were of oysters, clams, and scallops. Mingled with these were a few bones of fishes, birds, and small mammals."

The present writer takes this opportunity to express his personal obligation to Prof. Marsh, who thus called attention to the shell-heaps, and through whose courtesy a thorough exploration was made possible.

Geology.

Before commencing a description of the shell-heaps, it may be well to state briefly the geographical position of Block Island, and some of the theories concerning its general geological relation to the adjacent islands and the mainland. An outline map of this region is shown on Plate III.

That the same geological formations are found on the long series of islands reaching from New York to Martha's Vineyard, is the decision of geologists who have made a study of them. That the superficial stratum is of glacial origin is also agreed upon by all. Until recently, however, there has been a wide diversity of opinion as to the age of the basal clays that form the lowest visible beds of the series. Several authors have made passing reference to possible connections of certain of these islands with each other and with the mainland, but their discussions have been chiefly confined to geological periods far removed from the present day, while the geographic conditions during post-glacial time, which are of closer and keener interest to the zoologist, have been disregarded.

Prof. Marsh writes (this Journal, vol. ii, p. 295, October, 1896): "That Block Island was once connected with Long Island is suggested by a glance at a map of the New England coast, and that the same great moraine extended over both is evident from facts well known. An examination of Block Island itself, however, soon proved to me that these glacial deposits were merely a superficial covering, while the main body of the island was formed of much older beds, the exact age of which offers a most interesting problem." These beds, he states, are composed of variegated fresh-water clays similar to the plastic clays of Long Island and Martha's Vineyard. The indications are that they were deposited in the quiet waters of a basin which was formerly separated from the Atlantic Ocean by a great barrier that has since been destroyed by erosion and subsidence.

Prof. Shaler, in his "Report on the Geology of Martha's Vineyard" (Rept. U. S. G. S., p. 304, 1885–6), while treating of this series of islands, refers to the "considerable gap . . which divides Martha's Vineyard from Block Island." Continuing, he says: "The cause of this break is not perfectly

clear, but it is probably due, not to any failure of the glacial deposits to be formed in this space or in any considerable degree to their erosion, but rather, it is likely, to the fact that the floor on which they rest was originally lower in this part of the coast than elsewhere. This is indicated by the circumstance that from the western end of Martha's Vineyard there is a shoal that extends to Block Island and thence to Long Island. This shoal seems to be a continuation under water of the glacial mass to which Long Island and Martha's Vineyard belong." In the same report (p. 349), he expresses the belief that Martha's Vineyard has been connected with the mainland since the close of the glacial period, and adds that the animals and plants of the island are in no way peculiar, there being a few species existing on the mainland which are not found on the island, but none on the island which are altogether limited to it. He also makes the following statement: "We can hardly believe that several large-seeded plants and many of the land animals have found their way across the five miles of water which separates the Vineyard from the continent."

Turning to the United States coast charts, it will be seen that it is eight nautical miles from Block Island to the nearest part of the mainland, the maximum depth of water in the intervening channel being twenty-two fathoms. The straight course from Block Island to Montauk Point is twelve nautical miles, but here the soundings are far less than those taken in the waters to the north and east of the Island, doubtless because of extensive shoals formed by the tidal currents. These shoals stretch from the Island and from Montauk Point toward the middle of the intervening channel, at which point there is apparently a sudden increase in depth to between thirteen and sixteen fathoms. The character of the bottom over these shoals is hard, with occasional rocky localities. In fact, it is essentially the same as that of the bars underlying Plum Gut and the channels east and west of Great Gull Island.

In this Journal (vol. xl, No. 240), appeared an article by Prof. J. D. Dana entitled "Long Island Sound in the Quaternary Era, with Observations on the Submarine Hudson River Channel." The theories there set forth were the result of close inspection of soundings taken between the years 1878 and 1883. Apparently the author did not trace the former course of the Connecticut River with perfect confidence, for he took up and dismissed the subject in the following paragraph:

"As regards the existence of a submarine Connecticut channel the evidence referred to is certainly unsatisfactory. The bend in the bathymetric lines on the accompanying map be-

tween Montauk Point and Block Island looks right for such an origin, and strongly so. But considering the effects of tidal scour during the ebb through the narrow passages of the Sound, briefly referred to above, it is plain that the channel is of this kind. Block Island and Montauk Point stretch out under water far toward one another, and therefore the deepening from 12 fathoms to 27 and 30 over the narrow interval is a reasonable result for scour. The loops farther south in the bathymetric lines are too broad to be relied on for any conclusion . . . but tidal scour accounts well for the present condition of the region." The case briefly stated is this: In 1890, it was Prof. Dana's opinion that decisive evidence was wanting to prove that the original bed of the Connecticut River passed between Montauk Point and Block Island, for the tidal action, he said, was itself able to scour out such channels as were then supposed to lie on the north and south sides of the bar connecting the Island with Montauk Point.

Prof. Dana's bathymetric lines were plotted from soundings taken between 1878 and 1883, as has been already stated. It is a significant fact, and one to be carefully noted, that similar bathymetric lines, plotted from more complete and extended series of soundings, taken off Montauk Point in the years 1895 and 1896, show that the channel leading seaward from the bar is longer, deeper, and more pronounced now, than it appeared to be when Prof. Dana wrote that it "looked right" for a river-bed origin. The depression which then appeared to be a mile and a half long is now known to be ten miles long. It is not conceivable that this channel should have been enlarged to so great an extent by the ebbing tides during the past fifteen years; and the only conclusion possible is that this channel is the old Connecticut River bed, which Prof. Dana considered doubtful because soundings had not been thoroughly taken over the critical region.

The Shell-heaps.

Three shell-heaps of considerable size were explored by the writer during the year 1897. They will be mentioned in this paper under the names of the Fort Island Shell-heap, the Mott Shell-heap and the Cemetery Shell-heap. Their position is shown on Plate II. In addition to these, two very small deposits of shells, bones, etc., were discovered by systematic sounding in the immediate vicinity of the Cemetery Shell-heap, and a tract of land on the west bluff of the Island was found to contain numerous small deposits mainly composed of fish bones. There is no reason for supposing that these are all the shell-heaps formed during the occupancy of Block Island by the Manissees or their predecessors. On the contrary, it is quite possible that other deposits are still con-

cealed beneath the surface of some of the grassy hillsides draining into the fresh-water ponds. Moreover, the shifting sand-dunes now overlying much of the narrow parts of the Island on the east and west sides of the Great Salt Pond may, at some future time, uncover the sites of abandoned Indian villages. Shell-heaps may again be exposed when roads are constructed or repaired, and a careful search through the ploughed fields would undoubtedly yield a rich harvest of stone arrow-points and spear-heads.

The Fort Island Shell-heap.

The Fort Island Shell-heap originally covered the center and highest part of the island, which is situated near the middle of the small but deep Trim's Pond, now emptying into the Great Salt Pond. The indications are that at one time this shell-heap consisted of a circular deposit about fifty-five feet in diameter and two feet or more in depth at the center, the layer of shells, etc., thinning gradually toward the margin.

About ten years ago, in constructing the "New Road" from the Old Harbor to the Great Salt Pond, a cut several feet deep was made in a northwesterly direction across the middle of this shell-heap, and the thrifty workmen used the excavated material for filling in the pond where the road should cross it on each side of the island. If any confidence can be placed in the account given by the laborers who were engaged in the work, it would seem that archeological specimens of great value were thus destroyed or lost.

In April, 1897, the greater portion of what then remained was explored. The deposit on the northeast side of the cut was of small extent, and proved of little interest beyond marking the boundary of the original heap. It was a layer having an extreme depth of six inches, and composed of a black soil in which were scattered a few shells and bone fragments. On the southwest side of the cut was exposed a section of the shell-heap fifty feet long and about eighteen inches deep at the middle of the section, from which point the depth gradually diminished toward the margin in both directions. Near the middle of the section the layer was composed principally of shells mingled with bone fragments, the color of the mass being darkened by the intermixture of a fine black soil. Toward the northwest, the color of the layer became darker, and more fragments of bone were to be seen in proportion to the number of shells, the margin of the shell-heap showing a plentiful deposit of bones but no shells. At the other end of the section, the layer was composed almost entirely of shells and consequently was nearly white. When first seen from a little distance, the layer appeared to have twice its actual

depth, owing to the fragments of bone and shell which the rain had washed down from their original position near the top of the cut. The deposit was everywhere covered by a foot or more of poor soil under cultivation, which, strangely enough, yielded no surface specimens.

At this time, the road crossing Fort Island was being graded and hardened by the State of Rhode Island, and the engineer in charge obligingly detailed some of his workmen to grade the sides of the cut under the writer's direction, thus making it possible to save many specimens of value. Subsequently permission was obtained from the owner of the land on the southwest side of the cut, to explore that part of the deposit which lay beyond the boundary of the roadway, and much additional material was collected.

The following list gives the species of animals whose remains were found in this shell-heap, and also the names of the various manufactured articles:

Mammalia.

Homo sapiens (Man).
Cervus virginianus (Virginia Deer).
Canis familiaris (Dog).
Ursus americanus (Black Bear).
Lutra canadensis (Canada Otter).
Phoca vitulina (Harbor Seal).
Globiocephalus melas (Blackfish Whale).

Aves.

Corvus frugivorus (Crow).
Halietus leucocephalus (Bald Eagle).
Grus canadensis (Northern Brown Crane).
Bernicla canadensis (Canada Goose).
Fulix marila (Broad-bill).
Mergus serrator (Red-breasted Merganser).
Mergus merganser (Merganser).
Phalacrocorax dilophus (Double-crested Cormorant).
Larus argentatus (Herring Gull).
Colymbus torquatus (Common Loon).

Reptilia.

Chelydra serpentina (Snapping Turtle).

Pisces.

Gadus morrhua (Cod).
Centropristis striatus (Black Sea Bass).
Temnodon saltator (Blue-fish).
Lophius americanus (Angler).
Acipenser sturio (Sturgeon).

Mollusca.

Ostrea virginiana (Oyster).
Pecten irradians (Scallop).
Mya arenaria (Long Clam).
Venus mercenaria (Quahog).
Crepidula fornicata (Boat-shell).
Mytilus edulis (Mussel).
Modiola plicatula (Mussel).
Nassa obsoleta (Black Sea-snail).
Helix alternata (Land-snail).

Crustacea.

Balanus tintinnabulum (Barnacle).

Implements.

(Stone.)

Axe.
Spear-heads.
Arrow-points.
Knives.

(Bone.)

Bodkin.
Worked pieces of unknown use.

Pottery.

The Mott Shell-heap.

The other shell-heaps and smaller deposits to be described in this paper were explored during the month of July, 1897. The second shell-heap explored will be designated as the Mott Shell-heap, as it was situated on the northwest side of the lane which passes S. D. Mott's dwelling-house and a few rods from the "New Road." Fragments of shells cropping out at the roadside called attention to the presence of this shell-heap, which ultimately proved richer in vertebrate remains than any of the other deposits. Evidently a portion of this shell-heap, too, had been destroyed in road-making, for the horizontal plane of the layer was nearly semicircular with the straight side bordering on the lane. The greatest diameter of the layer was twenty-one feet, the least diameter about nine feet, and the depth a little over two feet. The shell-heap was covered by about ten inches of soil overgrown by a rich turf. The deposit consisted mainly of oyster and clam shells packed closely in the characteristic black soil, but in addition to these were found the remains of many species of mammals, birds, fishes, and reptiles, as well as numerous implements of stone and bone and bits of pottery. A careful examination of this shell-heap brought to light much valuable material, as will be seen by a glance at the following list:

Mammalia.

Cervus virginianus (Virginia Deer).
Canis familiaris (Dog).
Lutra canadensis (Canada Otter).
Phoca vitulina (Harbor Seal).
Phoca groenlandica (Harp Seal).
Halichoerus grypus (Gray Seal).
Globiocephalus melas (Blackfish Whale).
Castor canadensis (Beaver).

Aves.

Corvus frugivorus (Crow).
Bubo virginianus (Great Horned Owl).
Buteo lineatus (Red-shouldered Hawk).
Halietus leucocephalus (Bald Eagle).
Grus canadensis (Northern Brown Crane).
Bernicla canadensis (Canada Goose).
Fulix marila (Broad-bill).
Fulix ferina (Red-head).
Mergus serrator (Red-breasted Merganser).
Mergus merganser (Merganser).
Querquedula carolinensis (Green-winged Teal).
Oidemia fusca (Coot).
Phalacrocorax dilophus (Double-crested Cormorant).
Larus glaucus (Ice Gull).
Larus argentatus (Herring Gull).
Colymbus torquatus (Common Loon).
Colymbus septentrionalis (Red-breasted Loon).
Podiceps griseigena (Red-necked Grebe).
Alca impennis (Great Auk).
Utamanea torda (Razor-billed Auk).

Reptilia.

Chelydra serpentina (Snapping-turtle).
Terrapene carolina (Box Tortoise).
Chrysemys picta (Painted Tortoise).

Pisces.

Gadus morrhua (Cod).
Labrus tautoga (Tautog).
Centropristis striatus (Black Sea Bass).
Roccus lineatus (Striped Bass).
Lophius americanus (Angler).
Lamna punctata (Mackerel Shark)
Acipenser sturio (Sturgeon).

Mollusca.

Ostrea virginiana (Oyster).
Pecten irradians (Scallop).
Mya arenaria (Long Clam).
Venus mercenaria (Quahog).
Crepidula fornicata (Boat-shell).
Modiola plicatula (Mussel).
Mytilus edulis (Mussel).
Nassa obsoleta (Black Sea-snail).
Helix alternata (Land-snail).

Crustacea.

Balanus tintinnabulum (Barnacle).

Implements.

(Stone.)

Axes.
Disc.
Knives.
Spear-heads.
Arrow-points.

(Bone.)

Bodkins.

Pottery.

The Cemetery Shell-heap.

About an eighth of a mile south of the Great Salt Pond, and a few rods northeast of the cemetery, shells, bones, implements, and pottery were found together in a layer, which nowhere exceeded ten inches in depth, but was spread irregularly over an area of about seven hundred square feet. Because of its situation, it will be referred to as the Cemetery Shell-heap. The border of the deposit at the roadside had been broken up by ploughing, and at the time of exploration lay bare, while the rest was hidden by a few inches of soil which bore a strong turf. The list of the animal remains and implements obtained from this deposit is given below, and will be found to contain two vertebrate species not in the preceding lists.

Mammalia.

Homo sapiens (Man).
Canis familiaris (Dog).
Phoca vitulina (Harbor Seal).
Phoca groenlandica (Harp Seal).
Cervus virginianus (Virginia Deer).
Arvicola riparia (Meadow Mouse).

Aves.

Cygnus columbianus (American Swan).
Grus canadensis (Northern Brown Crane).
Fulix marila (Broad-bill).
Mergus serrator (Red-breasted Merganser).
Oidemia fusca (Coot).
Querquedula carolinensis (Green-winged Teal).

Pisces.

Lophius americanus (Angler).
Lamnapunctata (Mackerel Shark)
Acipenser sturio (Sturgeon).

Mollusca.

Ostrea virginiana (Oyster).
Pecten irradians (Scallop).
Mya arenaria (Long Clam).
Venus mercenaria (Quahog).
Crepidula fornicata (Boat-shell).
Mytilus edulis (Mussel).
Modiola plicatula (Mussel).
Helix alternata (Land-snail).

Crustacea.

Balanus tintinnabulum (Barnacle).

Implements.

(Stone.)

Knives.
Spear-heads.

(Bone.)

Fish-hook.

Pottery.

Other Localities.

About an eighth of a mile south of the Cemetery Shell-heap, a thin deposit was discovered under the turf at the roadside. It covered an area of only fifteen or sixteen square feet, and yielded few specimens of interest. From it were taken fragments of pottery and the remains of the following species of animals:

Phoca vitulina (Harbor Seal).
Acipenser sturio (Sturgeon).
Terrapene carolina (Box Tortoise).
Ostrea virginiana (Oyster).
Venus mercenaria (Quahog).
Mya arenaria (Long Clam).
Mytilus edulis (Mussel).

A second small deposit, similar to that last described, was found at the side of the lane immediately south of the cemetery. It contained fragments of pottery and the remains of four species of animals, viz:

Lamnapunctata (Mackerel Shark)
Mya arenaria (Long Clam).
Pecten irradians (Scallop).
Helix alternata (Land-snail).

The west bluff of the Island between Grace's Point and the Gut is covered for the most part with sand dunes, some of them grassed over, others unprotected and probably still being drifted by the gales which sweep the Island. Those which are protected by grass may possibly have retained their form and position on the bluff for many years. This much at least is certain: in many places under their surface, at depths varying from a few inches to a foot and a half, small deposits of shells and bones were found. With these animal remains were fragments of pottery and a few stone scrapers or knives as well as many refuse flakes of quartz and quartzite. From this locality the following species were obtained:

Cervus virginianus (Virginia Deer).
Phoca vitulina (Harbor Seal).
Grus canadensis (Northern Brown Crane).
Podiceps griseigena (Red-necked Grebe).
Temnodon saltator (Bluefish).
Acipenser sturio (Sturgeon).
Venus mercenaria (Quahog).
Mya arenaria (Long Clam).

On the accompanying map of Block Island (Pl. II) the positions of the shell-heaps and deposits are marked thus *. As may be seen, they are without exception placed close to the Great Salt Pond, where the Indians probably obtained most of the bivalves used for food. The mussels, however, which they consumed in large quantities, were no doubt gathered from the rocks lying awash off the sea-beaches of the Island. The problem of existence must have been simple for the Manissees when they were not at war with the Montauks and Narragansetts, for they apparently had an abundance of shell-fish in the Great Salt Pond within bowshot of their villages, and a plentiful supply of fresh water in the ponds which are to be seen in nearly all the clay-lined basins throughout the Island.

Age of the Shell-heaps.

In many places along the Atlantic coast of North America, indications as to the age of shell-heaps explored have been furnished by the overlying forest mould and by large trees of slow growth whose roots have forced their way through the deposits. Block Island, now denuded of its wealth of forest trees, affords no such evidence of the age of its shell-heaps, and reliance must be placed upon those indications which are obtainable from the contents of the deposits themselves and from the few existing references to the early history of the Island. In 1636, the Massachusetts Bay Colony, in revenge for the murder of John Oldham by the Manissees, sent an armed expedition under the command of Capt. John Endicott to make conquest of Block Island. This was accordingly done to the extent of killing fourteen Indians and maiming others, killing several dogs, burning many deserted wigwams and "great heaps of pleasant corn ready shelled," and carrying away "many well-wrought mats and several delightful baskets." From the records of the Massachusetts Bay Colony, under date of October 19, 1658, the following extract is made:

"This Court, in consideration of the honnored Gouernor, Jno. Endicott, Esq, his great services to this country, together with the good services of Rich Bellingham Esq, Dept Gouernor, and in respect of Major Gen Daniell Dennison, his great paynes in transcribing the lawes, & in regard of Major

Wm Hawthornes surrendring his seven hundred acres of land formerly graunted to him, doe relinquish theire clayme, & do graunt all their right & interest that this Court haue or might haue in Block Island to the above mentioned fower gentn, to each of them a quarter parte." In 1660, these four gentlemen sold their title to the Island to a company of sixteen men who took possession early in the following year; and from that time on the Island was controlled by the English. The presence in the shell-heaps of a variety of primitive implements of stone and bone, as well as refuse flakes of quartz, and the absence of all fragments of metal or European earthenware, make it obvious that these shell-heaps were formed before the colonization of the Island by the English. How long before that event the oldest deposits were laid down is purely conjectural.

Condition of the Vertebrate Remains.

The vertebrate remains found in the different shell-heaps and smaller deposits were damp when first removed, owing to their proximity to the surface and to the frequent and heavy rains which fell during the time of exploration. With the exception of fragments of the larger bones of the deer, which had resisted the action of frost and moisture to some extent, they were soft and liable to crumble in spite of great care taken in removing and preserving them. They were wrapped in cotton and allowed to dry slowly for several weeks. At the end of that time, they were found to be dry, light, and very brittle, and the readiness with which they absorbed moisture from the tongue or wetted finger showed that, during a long period of underground weathering, they had lost much of their organic composition. Very few of the bones were perfect. The shafts of the limb bones of the deer and dogs had been broken for the marrow they contained, though no pains had been taken to split them lengthwise. The articular ends of the long bones of the bird skeletons were often missing from the shafts, and in some cases marks of teeth were visible where these softer parts had been gnawed away, probably by dogs. A few of the bone fragments were charred, and a large proportion of the rest had been darkened to some extent by exposure to fire.

The Great Auk.

The fact that the bones of the Great Auk were found in two shell-heaps, viz., the Mott Shell-heap and the Cemetery Shell-heap, is of interest, since it adds to the knowledge of the distribution of this extinct bird. In an article by Mr. Frederic A. Lucas entitled "The Great Auk" (Rept. Nat. Mus., 1889),

a chart is given showing the localities in which remains of the Great Auk have been found in Indian shell-heaps. Although Mr. Lucas gives no locality south of Cape Cod, he says that this bird was probably common along the New England coast. So far as the writer can learn, the only evidence of its presence south of Cape Cod is to be found in Brereton's "Account of the Voyage of Gosnold to Virginia," where mention is made of "penguins" in the list of birds of the country. The date of Gosnold's arrival in Virginia was April 26, 1607.

A theory has been advanced by Fannie P. Hardy (The Auk, July, 1888) that the New England shell-heaps were formed principally during the summer encampment of the Indians at the shore, and that the finding of auk bones throughout the deposits points to the presence of these birds on the coast during their breeding season. In regard to the Block Island shell-heaps, there is no reason for supposing that they were deposited during the summer only, or even principally. On the contrary, the remains of many birds which visit our coast in the autumn and early spring rather indicate a permanent residence of the Indians there. Furthermore, the fact that all the auk bones found belonged to mature skeletons is opposed to the theory that these birds bred on the island.

The Gray Seal.

While exploring the Mott Shell-heap, part of a skull of the Gray Seal (Halichoerus grypus) was discovered. This consisted of a left maxillary and its premaxillary, with a nearly complete series of the teeth borne by these bones. A few small fragments and phalanges were found near the imperfect skull, and probably belonged to the same skeleton, although they have not been identified with certainty. The teeth in place were the second and third incisors, the canine, and the five teeth of the premolar and molar series. This seal had evidently reached an extreme old age, for all the teeth were much worn, especially the incisors and canine, which had been ground down until their pulp cavities were exposed to view. Only one individual of this rare species of seal was obtained from the Block Island shell-heaps, and there is no reason to suppose that it frequented the waters around the Island in such numbers as did the Harbor and Harp Seals. Yet its occurrence here is of interest when what has been written about its distribution is taken into consideration. From J. A. Allen's "Monograph of the North American Pinnipeds," the following quotation is made: "The Gray Seal appears to be not only one of the least abundant of the northern Phocids, but also to be restricted to a rather narrow range. It is wholly confined to

the North Atlantic, and even here is found within comparatively narrow limits. On the American coast, it occurs as far southward as Sable Island, Nova Scotia, where its presence is attested by specimens in the National Museum, collected there by Mr. P. S. Dodd. This, however, is the southernmost point at which it is known to occur."

Great Salt Pond.

The large size of the oyster- and other shells in the deposits is worthy of note. Oyster-shells measuring seven inches long and of ordinary proportions were of common occurrence in the deposits, and most of the clams and scallops also were well grown. Barnacles three-quarters of an inch in diameter were found in the shell-heaps. These had evidently been brought from the pond, attached to scallops, for the bases of the barnacles showed the imprint of the scallop-shells they had grown upon. From the earliest time of which tradition speaks, the Great Salt Pond yielded an abundant supply of oysters, clams and scallops, which leads to the supposition that it was more or less open to tidal flow. But about twenty years ago, the breach had apparently filled up, for at that time the last boatload of oysters was shipped from the Island.

In the "Fisheries of the U. S.," 1887, is found the following statement: "A narrow roadway that is often overflowed separates this pond from the sea. By many this pond is supposed to be sustained by springs flowing from the surrounding hills; others claim that it is supplied from the ocean by the water filtering through the narrow beach, and that its brackishness is caused by a partial evaporation of the salt. Enough salt is retained from this cause, as well as from the overflow from high tides and storms to sustain oysters and other shell-fish up to about half growth, at which time they die. A breach through the beach into the sea is much needed, and this question is now agitated by the inhabitants. With a small outlay thousands of bushels of fine oysters could be made to add to the yearly income of the fisheries."

Recently a deep "gut" has been dredged through the narrow beach on the west side of the Great Salt Pond, in order to make a harbor for medium-draught vessels, and the supply of fresh water from the springs at the shore of the pond is so small comparatively, that the water of the harbor is now practically as salt as the pure sea water. It remains to be seen whether the oyster fishery, which was one of the chief means of support of the prehistoric inhabitants of the Island, will be revived by the Block Islanders of the present day.

Distribution of the Fauna.

With the exception of the Great Auk and the Gray Seal, the vertebrate animals whose remains have been found in the shell-heaps were probably of common occurrence along the southern New England coast at the time of the coming of the English. Many of the species of birds now pass in their annual migrations to and from their breeding-places in the north, and a few are known to breed in this part of the country. That great numbers of edible sea-fowl should have been taken by the Indians is nowise remarkable, for the fresh-water and brackish ponds scattered over the Island must have been attractive feeding-places for these birds. The reptiles and fishes are all to be found in this latitude as well as in other localities farther north and south; and there is little indication that the shell-heaps date back to a remote period when a colder climate prevailed. The finding of many individuals of the species of Harp Seal and Gray Seal might be considered evidence of a sea-temperature lower than that of the present time, but such an inference can hardly be drawn from the discovery of the remains of only three Harp Seals and one Gray Seal.

During the time spent in exploring the shell-heaps, the writer's attention was attracted by the batrachians and reptiles which are now plentiful on the Island. Two species of tortoises were found, *Chrysemys picta* and *Cheldra serpentina;* and also two species of snakes, which were probably *Bascanium constrictor* and *Eutaenia sirtalis.* Capt. Uriah B. Dodge, the Harbor Master of Block Island, has taken a kindly interest in the present investigation. In reply to a letter asking what species of reptiles he had observed on the Island, he writes: "As to snakes, there are a few garter snakes and water snakes. One or two black snakes have been seen.

"There are plenty of pond turtles—green ones, and some big snapping turtles. Very large sea turtles are caught occasionally."

It is possible that the pond turtles may have been brought to the Island and there liberated, or that they may have been driven across from the mainland by heavy northerly gales. But in the case of the snakes, now represented on the Island by at least three species, the probabilities are decidedly against the theory of artificial introduction either by the white settlers or by the Indians. Although Capt. Dodge does not mention the common box tortoise in his letter and the writer has not seen it alive on the Island, yet abundant remains of this species were obtained from two shell-heaps. As it is probable that the tortoises now found on the Island are of the same stock as those taken by the Indians, any theory that explains the occur-

rence of the modern Chelonidæ can be applied equally well to those of prehistoric times. Similar problems of distribution arise in the case of the land mammals represented in the shell-heap collections. Like the reptiles, they may possibly have been transported by natural or human agency, or some of them may have traveled there on the ice just before the final retreat of the great glacier; but their occurrence may be explained in a simpler and more satisfactory way which will not antagonize the accepted theories concerning the recent geology of the New England coast and the distribution of its fauna. In order to do this, it will be necessary to ascertain what surface conditions prevailed on the Island until about two hundred and fifty years ago, and also to consider some evidences of change in level during the recent period.

Mr. Livermore's "History of Block Island" contains an interesting chapter on "Peat and Timber," giving many valuable references to the forest trees of the Island. Mr. Livermore writes that "a heavy growth of timber covered much of the surface of the Island at the time of its settlement;" and that "the kinds of timber most common here were oak, elm, pine, hickory, ash and cedar, with a thick growth of alders in swampy places, which were small and numerous." In regard to the peat deposits the same author states that "the beds are also numerous, and in every part of the Island. Some cover several acres, and others are much smaller. Some are shallow, and others are deep, and most of them were formed by vegetable matter, leaves, bark, nuts, grass, ferns, decayed wood, etc., that for ages had been washed down the surrounding steep little hillsides. Thus peat beds were deposited upon some of the highest parts of the Island, as upon Clay Head, and the supply was ample, if not exhaustless." Mr. Livermore makes this statement also: "In the peat deposits roots and trunks of large trees are frequently discovered."

From the foregoing quotations, it is evident that, long before the Island was discovered by Europeans, it bore a rich growth of those species of forest trees which are now found on the mainland; and the peat deposits imply the former existence of many ponds and swamps scattered over its forest-clad surface. With the destruction of the trees and the constant diminution of the Island itself, owing to the erosion of its shore, the number and size of the fresh-water ponds have become less, and consequently many of the springs on the hill-sides have failed. Still, even now, the supply of water would be sufficient for the support of many kinds of wild animals.

Evidence of the old Connecticut River channel between Block Island and Montauk Point has been already referred to in this paper. Attention is now called to the fact, obvious

though it is, that a river bed implies the existence of land on both sides to form the banks, and therefore it seems probable that at the time when the Connecticut River was scouring out its deep channel across the continental margin, there was a land connection of Block Island with the mainland. Just when the destruction of this land connection could have taken place is not clear; but some light upon this important question may be obtained from the evidence that at a comparatively recent time Block Island has undergone a submergence of several feet.

In a paper entitled "On Pleistocene Changes of Level in Eastern North America," by Baron Gerard De Geer (Proc. Boston Soc. Nat. Hist., 1892), is to be found much information regarding submergence along the southern New England coast. After reviewing the condition of the west shore of New Haven harbor, the writer says: "These facts seem to be in accordance with the assumption that this coast is slowly sinking, and I failed to find any proofs that since the ice age the land was ever more deeply submerged than it is now." Of Martha's Vineyard, De Geer makes this statement: "On Martha's Vineyard, where I had the advantage of Prof. N. S. Shaler's guidance, I could only confirm his observation that no raised beaches of any kind were to be seen."

Block Island nowhere exhibits raised sea-beaches indicating recent emergence; but, on the contrary, in certain places, former pond bottoms are exposed in the shelving bluffs only a few feet above the level of high tide, and according to Mr. Livermore, from whose history several quotations have already been made, "three [peat] beds of considerable known size, that may be larger than known to be, one on the east side of the Island, and two on the west, extend a considerable distance from the shore into the ocean." No specimens of peat from these beds are obtainable for examination at this time of writing; yet, judging from their description, they present many points of similarity to the submarine peat beds of Nantucket, of which Prof. Shaler, in concluding his discussion of the fossiliferous deposits of Nantucket (Geol. of Nantucket, 1889), writes: "So far as I am informed this is perhaps the clearest evidence which has been obtained showing recent subsidence along this part of the New England coast. As to the date of the subsidence no evidence seems obtainable from this locality. The peaty matter has a very fresh and unconsolidated aspect. The roots of the rushes which it contains are singularly recent looking; they are little decayed, and indeed seem to retain some part of their color and odor."

The eastern part of Long Island is being slowly submerged, for similar peat-beds below high water mark are also reported

from Montauk Point. Dr. Hollick of Columbia University, referring to the phenomena of submergence and erosion, says (Trans. N. Y. Acad. Sci., xvi, p. 17, Dec. 15, 1896): "Should they continue in the future it requires but little prevision to appreciate that Block Island and the islands to the eastward will continue to shrink in size, disappear, and eventually form merely parts of the shoals which now connect and surround them. Montauk Point will continue to recede, and, by the submergence of the low narrow strip of land in the vicinity of Canoe Place, a new island will be formed from what remains of the Point."

In view of this clear evidence of the sinking of the chain of islands lying off the southern New England coast, it appears possible that the land connection of Block Island with the mainland was raised above the sea-level at the close of the Glacial Period, and was not again submerged until some time during the Recent Period when the fauna of the New England region was essentially the same as it is now. There would then have been an opportunity for the distribution of the animals of the mainland over a large peninsula which is now represented by the rapidly dwindling Block Island.

The dogs, no doubt, were originally brought from the mainland by their masters, and therefore must be excepted from any conclusions which may be reached in regard to the indigenous fauna of the Island. But, as has been shown, the surface condition of Block Island when settled by the English was such that there is no reason why all other animals named in the foregoing lists could not have been supported. Moreover, it is unlikely that the Manissees, a tribe frequently at war with their neighbors, the Narragansetts and Montauks, would have carried quantities of fresh meat from the mainland in their canoes, when their own country and its surrounding waters supplied them with an abundance of fish, shell-fish and sea-fowl.

This hypothesis is certainly well borne out by the rich growth of forest timber once covering the Island, and, in the opinion of the present writer, it offers the best solution of the problem of distribution arising from the presence of the remains of land animals in the prehistoric shell-heaps.

Archeological and Ethnological.

There are several topics connected with the description of the Block Island shell-heaps which deserve notice here, although they are quite apart from the discussion of the fauna. One of these, the discovery of human remains under peculiar circumstances, is of especial interest.

Human Remains.

Just within the western margin of the Fort Island Shell-heap and about a foot below the surface of the ground, a human skull was exposed. It was found impossible to remove the skull intact; so after carefully scraping and brushing away the surrounding earth, an examination was made before lifting it from its bed in the ground. The greater part of the brain-case was apparently uninjured, but the lower part of the parietal region of the left side was fractured and crushed. The lower jaw was complete and in place.

The dentition of the jaws is that of a child of about seven and a half years of age. Although the enamel has been much worn from the crowns of the deciduous teeth, exposing large tracts of dentine, there are no cavities caused by decay. The crowns of the canines are ground to flat surfaces, but it is impossible to ascertain the character of the edges of the incisors, whether worn by cutting or grinding, as the deciduous incisors have been shed and none of their successors are sufficiently advanced to show any marks of wear. The skull is now in fragments that cannot be assembled; but when first examined before removal from the ground, it showed little variation from the average type of skull of the New England Indians.

Excavating in the direction indicated by the position of the skull, remains of vertebræ and ribs were next uncovered, though their condition at the time of burial could not be ascertained, as they were poorly preserved. Of the vertebral series, only the axis and part of the atlas were successfully removed. A portion of the left scapula was saved, while the right scapula was so decomposed that removal was impossible. None of the bones of the hands and arms were found. Most of the pelvis was removed, though not without injury, owing to its brittle condition. The right femur was in place and entire, but not the slightest trace was found of the rest of the limb. The bones of the left leg were in place and were complete down to a point two or three inches above the lower articular ends of the tibia and fibula. These articular ends were wanting, as were also the bones of the foot, though it is to be noted that, at the margin of the shell-heap and about seven feet from the rest of the skeleton, a left astragalus was found, poorly preserved and of such size that it might well have been part of this skeleton. The fractured ends of the tibia and fibula had weathered to the same hue as the natural surfaces of the bones.

The skeleton throughout was in a poor state of preservation, the bones became very light and brittle after drying slowly in cotton-batting, and their peculiar feeling, when touched by the tongue, gave evidence of long underground weathering.

The only limb bones which afforded measurements were the two femurs; their lengths were found to be eleven and a quarter inches, indicating a total stature of about forty-two inches. A careful search brought to light no other human bones from this shell-heap.

Cannibalism.

The discovery of this skeleton is of especial interest to the archeologist, inasmuch as it throws light on the subject of the prevalence of cannibalism among the Indians of the New England coast. That the child whose skeleton has just been described met with a violent death was suggested by the defective condition of the left wall of the skull, though whether a blow causing such a fracture was given in the act of capture or as a coup-de-grace would be fruitless to discuss. Further, the fact that the skeleton had been apparently cast upon the heap of shells, bones, wood ashes, and broken cooking utensils, is suspicious, and does not indicate the slightest degree of that reverent care usually observed in the Indian funeral ceremony. The absence of the arms and of portions of the lower limbs can best be accounted for by supposing them to have been cut off for greater facility in cooking. The places of amputation point to a crude knowledge of anatomy, for the shoulder and knee joints are those which a savage could best divide with his rough stone knife, and after failing to master the nicety of the ankle joint, he might be tempted to try a few inches higher up, at the small of the leg, where he would at least be unhindered by any complex articulation.

An ingenious theory has been advanced to account for the finding of this human skeleton in a shell-heap. Believing that it has not appeared before, the writer states it here briefly. When a death occurred during the cold winter months, it would have been difficult for the Indians, provided only with rude mattocks of stone or wood, to dig a grave in the frozen ground; yet under their fires, which were probably located within the limits of their shell-heaps or at least close to them, there would have been little or no frost in the ground, and a grave could have been dug with comparative ease. This theory might account for the occurrence of a complete skeleton in a shell-heap, but it fails to satisfy the requirements of the present case, where a skeleton lacking the bones of arms and legs was found.

In the Cemetery Shell-heap, a piece of human skull was discovered consisting of parts of the frontal and left parietal bones. Judging from the development of the coronal suture, the fragment belonged to the skull of a fully mature individual. Although this is of less interest than the discovery of the child's skeleton in the Mott Shell-heap, it certainly adds somewhat to the evidence upon the subject under consideration.

Referring again to the murder of John Oldham by the Manissees, in 1636, the condition of Oldham's body when found may be particularly noted. Governor Winthrop describes the reprisal of the trader's sloop by John Gallop, and writes "and looking about, they found John Oldham under an old seine, stark naked, his head cleft to the brains, and his hand and legs cut as if they had been cutting them off, and yet warm." The reason for this attempted dismemberment of Oldham's corpse is readily understood if we accept the theory of cannibalism.

Stone Implements.

Stone implements are frequently found on the surface of the Island, though until this time little attention has been given them and few have been saved. Throughout the mass of each shell-heap, stone arrow-points, spear-heads, and knives or scrapers were found, nearly all of them made of quartz or quartzite, which are common bowlder materials. Besides these finished implements, there were quantities of irregular flakes showing some evidence of chipping. From the Fort Island Shell-heap, one roughly-made quartzite axe was taken; and from the Mott Shell-heap two large single-grooved axes, one of quartzite, and the other of a dark fine-grained porphyry; both of these had been carefully ground to sharp-cutting edges. Although a few well-made arrow-points of graceful shape were found, the average grade of workmanship shown by the shell-heap implements is much inferior to that displayed by the stone implements of the mainland. Indeed this lack of skill is sometimes manifest in the choice of material as well as in manufacture, for arrow-points were occasionally made of a dark gray argillite whose strong cleavage did not permit a good edge to be obtained by secondary chipping.

On the high wind-swept bluff near Grace's Point, an interesting discovery was made. The surface near the edge of the bluff is almost denuded of vegetation, and the finer grains of sand in the drift stratum are carried away by the wind as soon as they are exposed. Consequently the surface at this place is composed principally of glacial pebbles and coarse gravel. Many of the pebbles are of a fine quality of quartz or quartzite, well suited for the manufacture of the smaller stone implements. Here, within an area of about eight hundred square feet, was found a great number of worked stone pieces ranging through several stages of development from the simplest flakes to the finished arrow-points. Two of these are beautifully worked points of the tanged and leaf-shaped types which bear witness to far higher skill than do the implements

from the shell-heaps. This place was probably the site of an Indian workshop. So little has Block Island been explored, that these relics have remained for several years exposed to view at the top of the bluff. It seems likely, however, that for two centuries or more sand dunes have covered this part of the west shore of the Island. Another result of the drifting sand was shown at Crescent Beach, where an arrow-point was dug from the top of the glacial stratum which was overlaid by eighteen inches of black forest mould and five feet of drifted sand.

Implements of Bone.

In strong contrast with the crudeness of most of the stone implements is the finished character of the bone articles obtained from the shell-heaps. Three bodkins of deer bone were found. One of a slender willow-leaf form, about three inches long and half an inch wide, is ground to a sharp tapering point at one end, and at the other end bears a second smaller point protected in a clever way by a shoulder, so that a small hole could have been quickly made in a skin without the least danger of injuring or disfiguring the work. Another bodkin is about four inches long, and, except as regards its length, resembles a modern bone knitting needle. It is made from one of the long bones of a deer's skeleton. The shaft, which is nearly straight, has been carefully rounded and ground to a sharp point at one end, while the other end has been merely smoothed into the form of a rounded knob which may be rested against the palm of the hand.

Two peculiar bone articles whose use it would be hard to determine were taken from the Fort Island Shell-heap. One may have served as a scraper for dressing skins, for it is about three inches long and a little over an inch wide, and a sharp beveled edge has been ground upon one end. It is made from the right ulna of the American Black Bear. The other article is a piece of the left humerus of the same species of bear about two inches long and an inch wide, carefully ground to flat surfaces at the artificial sides and ends. It is remarkable that the Manissees, who were expert fishermen, should have left hardly a trace of their fishing-gear in the shell-heaps. One U-shaped bone object, which may be a broken hook, was taken from the Cemetery Shell-heap, but no entire hooks were found. Although the Block Islanders say that stone sinkers are occasionally picked up near the shore of the Great Salt Pond, none have been saved.

Ancient Pottery.

Broken pottery was taken from nearly all the shell-heaps and deposits explored, the yield of the Fort Island and Mott Shell-heaps being especially large. No attempt has been made to assemble the broken pieces, comparatively few of which are large enough to indicate the shape of the original vessels. But, so far as may be judged from these fragments, the ordinary form of pot had a rounded bottom and curving sides which were drawn in at the rim. A few were given an exceedingly graceful shape by letting the rim flare a little. The thickness of the fragments is from three-eighths to seven-eighths of an inch, and the largest pot had a diameter of fifteen inches. The material is apparently a mixture of clay with a small proportion of gravel and pounded oyster shells to make it fire better. The color of the pottery, when not hidden by a thick coating inside and out of soot and decomposed organic matter, is a dull red. It is evident from the grooves on the inside of many of the fragments that the potters frequently made use of large scallop shells which, owing to their bulging form, made excellent finishing tools. The grooves thus traced are very ornamental. That a pot finished in this manner could not be easily cleansed was probably thought of little importance.

A few fragments bear nearly obliterated lines outside, which resemble to a slight degree the impression of cords, but there is no certain evidence that any pottery was made in basket moulds. On the outside, ornamentation was often produced by scoring the pots with a toothed graining instrument. The result is especially pleasing to the eye when the lines traverse the pot obliquely. In some instances, the pots were first made smooth inside and out, and then some simple decorative designs were traced around the rims. One of the simplest designs consists of a triple girdle of dotted lines. Most of the vessels were pierced in three or four places for the passage of supporting cords, and on a few, the intervals between these holes have been marked by series of blind holes. Perhaps the most elaborate decoration is borne by a potsherd, which has its flaring rim ornamented with an oblique indentation. Around the narrowest part of the pot, an inch below the rim, runs a double girdle of dotted lines, close beneath which the holes for support are pierced, and these holes are surrounded by a fanciful fret design of dotted lines. In its form and decoration, this fragment shows that much taste and skill were exercised by the potter.

Conclusion.

Such is the brief account of the exploration of the prehistoric shell-heaps of Block Island, together with a statement of their contents, which were found to include a great variety of primitive implements and the remains of many species of vertebrate and invertebrate animals. The bones of the land animals seem at first to be strangely out of place upon a small island several miles out at sea; and the necessity is immediately felt for some explanation of their occurrence there. In view of the number of modifying factors which must have affected the distribution of the fauna over this interesting region, it is difficult to formulate a theory which shall satisfactorily explain the way in which the land animals came there. Still, in many cases, it is possible to arrive at conclusions which are supported by the weight of strong probability, and certainly all the known conditions of the problem are satisfied by the hypothesis which has been advanced; namely, that the area of land now represented by Block Island already possessed a considerable "mainland fauna" at the time of its separation from the continent. Whether this supposition is correct or not may be determined by future investigation; and it is to be hoped that this will lead to further discoveries tending to throw light upon this subject, as well as upon questions connected with the history of the Indian tribe which the English colonists supplanted.

Yale University, New Haven, Conn., June 1, 1898.

Explanation of Plates.

Plate II.—Outline map of Block Island, showing location of Shell-heaps.

Plate III.—Outline of Southern New England Coast.

ART. XIV.—*A Registering Solar Radiometer and Sunshine Recorder*; by GEO. S. ISHAM, A.M., M.D.

THE object sought in making the machine about to be described was to get some simple form of registering apparatus which would give values in different places that could be compared, for that part of the total insolation of any place which goes to make it a source of convection currents, or what might be called the convectional potential of the place. To get absolute values for this seems an almost impossible thing to do, but if by any means reliable relative values can be obtained they will for many purposes be quite as valuable in studying the many problems of local winds, thunder storms, etc.

The black bulb is intended to represent any clod of earth or average matter exposed to the direct rays of the sun, and to all the winds that blow; the ordinary vacuum case is left off, as introducing far greater errors than it corrects. The shelter fulfills the above conditions as nearly as I can make it; a typical exposure would be an entirely unprotected one close to the ground. The position should be one that represents, as nearly as possible, the average of the locality.

The name solar radiometer is unsatisfactory, as it conveys the idea of a good deal more, and also something less, than is intended. Perhaps convectometer would be better. Its uses as a sunshine recorder, and as a means of measuring the heat given to vegetation are self-evident. For the latter use it would be better to color the tube green or treat it as De Blanchis has done in his investigations.

The machine has been given its present form as presenting a curve which requires the simplest corrections, there being no correction for pressure, specific gravity, or temperature. It is also simple enough to be understood and successfully run by persons not specially trained.

The instrument, in part like the registering barograph of Sprung, is made as follows: a long, straight scale beam C is balanced in the middle on a knife edge, resting on the support A. Each end of the beam supports on its upper side a perpendicular glass tube hung by a collar D fitted with knife-edge bearings, the collar being fastened a little above the middle point of the tube. These tubes dip into cups S, S1, connected together by a tube and capable of being raised or lowered by the screws T, T1. One of these tubes is covered with lamp-black above the collar.

Suspended from the beam by a rigid rod, with a screw thread on it, is the weight Q, by moving which balance may be

had in adjusting, and position of c. g. of the balance changed by changing its weight. On the beam next the blackened tube is a track on which runs the carriage E. This carriage is attached by the wire method, or by two universal motions to the arm F, which, in turn, is fastened to the nut G. The arm motion is limited to a right line parallel to the track by a rod which runs through a hole in the arm.

The nut G, which also carries the pen, is moved backwards and forwards by the screw H, geared to the perpendicular shaft I, which is broken by the universal motion J. The lower end of the shaft passes through a square block of soft iron, which block is limited by guides to a to-and-fro motion between the magnets K, K1; it then terminates in a gear wheel which engages either one of the wheels L, L1, according to which magnet is excited. A clock-work motor M, run by a weight and governed by a fly-wheel, turns the shaft, on which are the two gear wheels L, L1, always in the same direction. This motor is started or stopped by the magnet N, the armature of which moves a check to the fly-wheel.

From the back of the beam, in the middle, is a long pointer, terminating in platinum contacts (shown at the end of the beam in the drawing to avoid confusion). One or the other of these contacts, on the slightest motion of the beam, touches the point R or R1. The contact R is connected with the magnet K, and the battery and the contact R1 with the magnet K1 and the battery. The other pole of the battery runs through the magnet N and to the plate B on which the knife edge of the beam rests; the plate and the arm F being insulated, only the scale beam is in circuit.

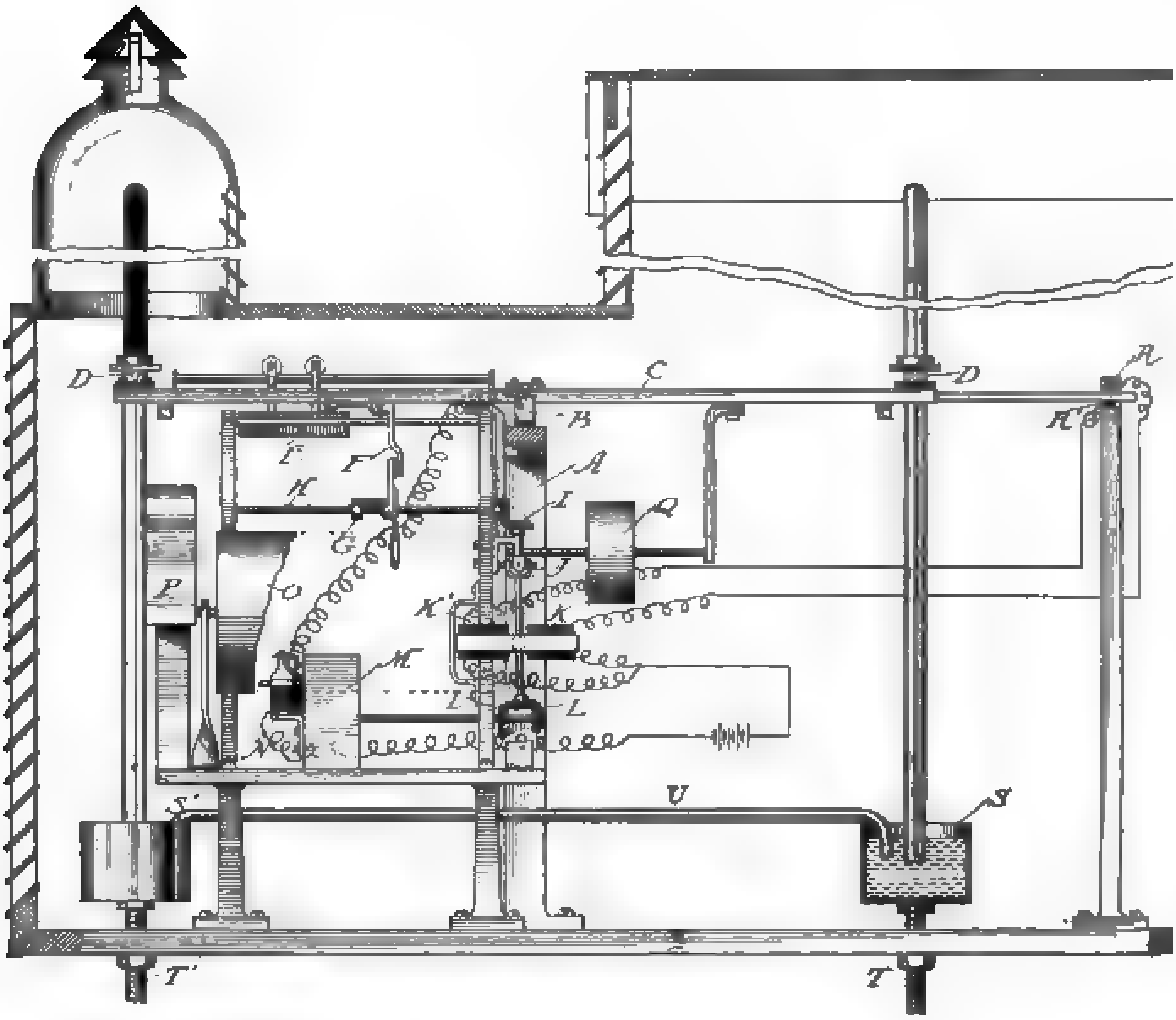
The tubes are filled with pure mercury and set in place in the same manner and with the same precautions as in filling a barometer tube, a liberal amount of mercury being left in the cups; the connecting tube is filled and put in place; then enough absolute alcohol is injected into each tube to insure, under all conditions of temperature and pressure, a saturated vapor of alcohol at the top.

An addition is built to the south side of an ordinary weather bureau shelter for thermometers, having a flat top and the same louver board sides; over a large hole in the top is put a glass cover; one-third of its circumference on the north is cut out and louver boards put in; on north side of the middle of the top of cover (not in middle as shown in cut) some form of lantern top is put. The ventilation must be as free as possible.

When the sun is not shining both tubes are of the same temperature and the tension of the alcohol vapor is the same in each; both tubes weigh the same, and the machine is in

equilibrium. This will be true whatever changes there may be in the temperature of the air, or the atmospheric pressure.

If the sun, or any source of heat, act upon the black tube the tension is increased, some mercury is forced out of the tube, the weight becomes less, contact is made at R1, the mag-



net K1 engages the wheel L1, the motor is started and the carriage is moved out upon the beam until the balance is restored, when contact is broken and the motor stopped.

When the source of heat is removed the tube cools, tension is decreased, amount of mercury is increased, equilibrium is disturbed, contact at R is made, and motion of carriage reversed and continued until equilibrium is again restored.

Secured to the nut G is a pen which moves with the nut parallel to the axis of a cylinder O, rotated once in twenty-four hours by the clock P.

The following dimensions for parts give good results: tubes ¼-inch inside diameter, 32·5 inches long; scale beam 30 inches.

The vapor chamber should be as small as possible, so the cups are arranged to be lowered or raised by screws in order to just accommodate, and no more, the largest probable change in temperature and pressure for the season, and to adjust for elevation above sea level. Because, as the tension of saturated vapor in any chamber is the tension of the coolest part; so the smaller the chamber the more sensitive it will be. The circumference of the cylinder O is 48 centimeters, which makes one millimeter equal three minutes of time. A difference of one millimeter in tension, by adjustment of the weight of carriage, causes a motion of two millimeters in the pen.

These dimensions seem to be large enough to nearly exclude mechanical errors and not too large for convenience. If more accurate values as regards time are required the motor should be arranged for two different speeds by having, for example, the first contact of the pointer made through a light spring, which starts the motor as above, but upon increase of weight it closes a second circuit which would raise a brake, or friction wheel, from the motor, thereby increasing the speed.

A motor that moves at a constant speed is either so slow that the pen falls behind a sudden change in temperature, or so fast that it causes oscillation on slight changes.

The use of a saturated vapor in this way I believe to be original. I have chosen ethyl alcohol as giving the best average results, though experience may prove that the use of ether in winter and alcohol in summer, or some such combination, may be better.

The difference in vapor pressure in millimeters of mercury of ethyl alcohol between 0° C. and 5° C. is about 5^{mm}, and lower down the difference is very much less, which would probably give inaccurate results.

To reduce the tracing on card there must be either a synchronous tracing, preferably on the same card, by a thermograph, or observations of a thermometer; for the curve represents the difference in temperature between a shaded and a black bulb thermometer.

The pen, when the sun is not shining, draws a straight line around the card which is the base line of measurement, but must have a different value for different temperatures. Suppose that at twelve o'clock, noon, on a certain day the curve measured $38·4^{mm}$ from the base, and at the same time a sheltered thermometer or the thermograph trace showed a temperature of 25 C.; then, as the tension of alcohol vapor at 25 C. is $58·86^{mm}$, adding half of the 38·4 (for the machine multiplies by two) the sum equals $78·06^{mm}$, equals tension at 30 C., equals temperature of black bulb thermometer at that time. This may be done by simple inspection by making a transparent scale as follows:

Take a strip of glass or transparent celluloid, lay off from a base line which is marked 0° C. 10·14^{mm}, and make another mark and number it 5° C., for this distance is double the number of difference in millimeters of mercury of pressure of alcohol vapor, between 0° and 5° C., and so on all the way up and down the scale from the zero, taking the numbers from tables and interpolating by graphic method, values for degrees not given. Having made the scale, lay it on the card and put for every reading you wish to make the number representing the degrees temperature shown by the thermometer for that hour over the base line; then where the curve crosses the scale is the temperature of the black bulb at that time.

In order to compare the values of the reading for the same day at different places, I would suggest the following: the paper I have used is ruled in square millimeters and centimeters. It can be bought in any of the shops and serves the purpose; all that is necessary is to cut it in strips of the requisite width and mark a few of the hours on the transverse lines.

When reading the actual temperature by the scale for every half hour, hour or two hours, according to the accuracy desired, make a mark on the hour line at the intersection of the millimeter line corresponding to the number of degrees of difference between the shaded and black thermometer; e. g. if the difference is 12° make a dot at the intersection of the 12th millimeter line (measured from the base) with the hour line being measured. When they are all measured, join all these dots, and the area of the surface included between the base, and the irregular line so made, is the measure of the local insolation.

The thermograph should be arranged to trace its curve on the other side of the base line, one millimeter for each degree, or the curve may be plotted; then the area of the surface included between the two irregular curves so made is computed by inspection or by a planimeter; the number representing this area is purely arbitrary, but gives a good method of comparing any number of cards of the same or different places.

I think there are no corrections to be made for instrumental errors, other than mechanical ones, which is the advantage in using a saturated vapor, except in case of sudden change of temperature, when, though the machine acts almost instantaneously, it is slower than the actual change, but compares very favorably in rapidity with ordinary thermometers either mercurial or alcoholic.

The many ways of varying the machine will be evident upon a little reflection. The form as shown is simply the one that seems to me to be best; a better way of exposing it might alter its form greatly and simplify it, but I do not know of one which will protect it from wind and rain.

ART. XV.—*The Tertiary elevated Limestone Reefs of Fiji*; by ALEXANDER AGASSIZ.

DR. WILLIAM H. DALL has been kind enough to examine the fossil mollusks which I collected from the elevated limestone reefs in Fiji. He confirms the impression I had formed of their late Tertiary age.

Dr. Dall writes: "The fossils comprise Turbo, Cassis, Lithophaga, Macha, Tellina, Meretrix, Dosinia, Chama, Pholas and fragments of Pecten. None of the genera are extinct. The rock, however, looks decidedly too old for Pleistocene. I should say the fossils were younger than Eocene and might be either Miocene or Pliocene."

The boring which I started at Wailangilala Island in the atoll of the same name, was only carried to a depth of 85 feet. For 40 feet the tool passed through coral sand similar to that forming the shores of the island; from that depth down to 85 feet, the core consisted of a limestone similar in all respects to the limestone composing the elevated reefs we had observed at Ngele Levu, at Vanua Mbalavu, at Mango, at Yangasá, at Oneata, at Ongea, at Kambara, at Vatu Leile and at different points along the eastern, southern and western shores of Vitî Levu. As at some points the elevated limestones attain a height of over 1000 feet (Vatu Vara Island, 1030 feet), nothing could be gained by continuing the boring at Wailangilala to obtain material which could be collected so readily in other localities; the boring was therefore abandoned.

The volcanic rocks underlying the elevated limestone reefs were observed at Vanua Mbalavu, at Mango, at Kambara and at several points along the southern and western coast of Viti Levu. To have continued to bore until we should strike the underlying rocks would have been equivalent to boring in localities where the base of the limestones had been but little elevated when it could be readily examined in the localities I have mentioned.

A renewed examination of the elevated reefs of the Paumotus, of the Friendly Islands, of the Gilbert, Ellice and other groups of atolls in the Pacific, will be needed to determine their age and correlation to the Fiji elevated limestones.

At any rate it is evident that the Tertiary coralliferous limestones of Fiji have not played any part in the formation of the atolls or islands encircled by recent coral reefs, beyond forming the substratum upon which the recent corals have grown and established themselves as a comparatively thin crust.

The underlying limestones have performed exactly the same part as the volcanic substratum in other islands of Fiji, such

as Totoya, Kimbombo, Wakaya, Makongai, Moala, Nairai, Ngau and others. In both cases the platform upon the top of which the corals grow has been prepared by extensive submarine erosion dating from the time when the limestones were elevated by the volcanic rocks which crop out everywhere in Fiji.

Professor David, of the University of Sydney, has been kind enough to assist me in obtaining the services of one of his students, Mr. E. C. Andrews, to collect fossils from the elevated reefs of Fiji. Mr. Andrews will spend a part of the summer in Fiji collecting material and exploring in detail some of the faces and slopes of the elevated reefs of the Archipelago, and I hope to obtain ample material to determine the age of these elevated limestones.

In the earlier discusions of the thickness of recent coral reefs by Darwin and Dana, no attention was paid to the possibility of the substratum of recent reefs consisting of Tertiary limestones. Elevated limestone containing corals of Tertiary age were considered as of recent origin and as pointing to a great thickness of modern reefs. It has been shown in Florida that the modern reef is not more than about 50 feet thick, and according to the borings from the artesian well at Key West is succeeded by Tertiary limestones, in which corals occur at intervals to a depth of 2000 feet.

It has been stated by Dana and others that the borings from the artesian wells at Honolulu to the rear of the shore line of the fringing reef of Oahu indicate a great thickness of modern reef corals. These statements are based upon the examination of samples of finely ground particles of limestone accompanied by an occasional fragment of coral, the age of which has not been determined. The statements are further supported by the evidence of Mr. J. A. McCandless, the engineer in charge of the boring, who asserted to Mr. Dana and myself that in boring all his wells the tool passed through a great thickness of corals, at various levels. During my recent visit at Honolulu I was fortunate to be on the spot when Mr. McCandless was boring a 10″ well about 2500 feet from the shore line and perhaps 7 feet above high water mark. Down to a depth of 80 feet nothing but recent reef coral rock was encountered, but from that point to a depth of over 300 feet the limestone passed through was of a very different character. It contained but few corals, being composed almost entirely of the shells of mollusks, mainly bivalves. The rock was white, chalky and resembled in every way the rocks of the Vicksburg age of Florida and of Yucatan; but their age has not yet been accurately determined. Enough, however, is clear to show that the limestones which form the substratum upon which rests the recent fring-

ing reef of Honolulu do not belong to the present period. Mr. McCandless assured me that limestones like those I had the opportunity of examining while the boring was going on, are identical with those to which he called Mr. Dana's and my attention in 1888, and that until I pointed out to him that the white limestone was almost wholly made up of Mollusca he had only paid attention to the occurrence of occasional corals and supposed the lower limestone to form the continuation of the recent modern reef. But as I have stated, this lower limestone differs from reef rock both lithologically and in its being made up of fossil mollusks.

It is very clear that when boring in a coral reef district in which it is difficult or impossible from other data to determine what geological changes may have taken place or the probable age of any limestone we may pass through in boring, it may be very easy to draw wrong conclusions both as to the age of the limestones and regarding the position of the line of demarcation between the modern coral reef and the underlying older limestone substratum.

If my conclusion that such atolls in the Fiji as Wailangilala, Ngele Levu and many others to which I shall refer in my final report, are formed upon platforms of marine erosion of elevated Tertiary limestones is correct, and if further in similar atolls in the Paumotus, the Gilbert, Ellice and other groups, the substratum underlying the modern coral reef is likewise composed of Tertiary limestones, it will become apparent that such boring as that carried on at Funafutî will not help us in any way to solve the problem of the formation of atolls by modern coral reefs. Such a boring, even should it reach the underlying volcanic substratum, will only give us the thickness of the Tertiary limestone beds forming the substratum upon which the modern coral reef has grown, a thickness which in the Ellice group can only be ascertained by boring, while in Fiji it can be ascertained approximately from the height of the islands composed of elevated Tertiary limestones.

Under what conditions these Tertiary coralliferous limestones of great thickness have been deposited is a distinct question from that of the formation of atolls through subsidence by the upward growth of corals during the present geological period. Neither the borings through a coral reef growing upon a substratum of Tertiary limestone, nor the examination of the outer edge of a coral reef formed upon a substratum of volcanic rocks, has given us (in Fiji) any evidence of the great thickness of a modern coral reef. On the contrary, all the evidence I have gathered in Fiji tends to prove that a coral reef forms only a comparatively thin crust upon the platform of submarine erosion (whatever be its geological structure) upon which it may have found a footing.

ART. XVI.—*The Iodometric Determination of Molybdenum*; by F. A. GOOCH and JOHN T. NORTON, JR.

[Contributions from the Kent Chemical Laboratory of Yale University, LXXII.]

A PROCESS for the iodometric determination of molybdic acid, which consists in treating a soluble molybdate in a Bunsen distillation-apparatus with potassium iodide and hydrochloric acid, has been advocated by Friedheim and Euler.* According to this process the molybdate, containing from 0·2 grm. to 0·3 grm. of molybdenum trioxide, is treated with from 0·5 grm. to 0·75 grm. of potassium iodide and enough hydrochloric acid, of sp. gr. 1·12, to fill two-thirds of the flask of the apparatus. The liquid is warmed until heavy vapors of iodine fill the flask and then boiled until iodine vapor is no longer visible and the color of the liquid residue is a clear green. The iodine liberated is collected in the distillate and titrated with sodium thiosulphate, every atom of iodine found indicating presumably the reduction of a molecule of molybdic acid to the condition of the pentoxide Mo_2O_5.

It was pointed out in a former article from this laboratory,† that greater precaution than was taken by Friedheim and Euler is necessary in order that the reduction may proceed according to theory, and that the iodine collected may serve as a reliable measure of the molybdic acid. It was found that the green color of the liquid comes gradually and that it may develop distinctly before the molybdic acid is fully reduced. It was found, also, that since even a trace of oxygen liberates iodine from the hot mixture of potassium iodide and hydrochloric acid of the strength employed, it is not sufficient to rely upon the volatilization of iodine to expel the air originally in the apparatus, but that it is essential to conduct the distillation in an atmosphere devoid of oxygen. The suggestion was made therefore that the operation should be carried on in a current of carbon dioxide and that the mixture, constituted definitely, should be boiled between stated limits of concentration which were determined by experiment. It was found that when amounts of a soluble molybdate containing less than 0·3 grm. of molybdenum trioxide are treated with potassium iodide, not exceeding the theoretical proportion by more than 0·5 grm., and 40^{cm^3} of a mixture of the strongest hydrochloric acid and water in equal parts, the reduction proceeds with a fair degree of regularity and is practically complete when the volume has diminished to 25^{cm^3}. If the operation is pro-

* Ber. d. d. Chem. Gesell., xxviii, 2066.
† Gooch and Fairbanks, this Journal, IV, ii, 156.

perly conducted in an atmosphere of carbon dioxide, it was shown that the iodine in the distillate may be trusted to indicate the molybdic acid within reasonable limits of accuracy. It appeared, however, that too great an excess of potassium iodide tends to induce excessive reduction, and that the same tendency shows when the liquid is concentrated to too low a limit.

To this criticism Friedheim took exception* and contrasted, to their disadvantage, our results by the modified method with those of Friedheim and Euler by the original method. It became necessary, therefore, to point out† the fact that of the results published by Friedheim and Euler, upon which reliance was placed to prove the reliability of their method, five out of seven in one series and one out of five in another series had been calculated incorrectly from data given. Another series of six determinations was, however, apparently faultless in this respect. More recently‡ Euler has explained that the errors were not really arithmetical. Two of them may be presumed, inferentially, to be due to careless copying or proof-reading; and four, we are told by Euler, were introduced into the series by mistake, and actually represent (as Prof. Friedheim kindly informs him) the analysis of a sample of ammonium molybdate of undetermined constitution: that is to say, the figures now given by Euler represent the original percentages of molybdenum trioxide which had been changed by some unconscious process from

80·62	per cent	to	81.85	per cent.
80·71	"	"	81·69	"
80·63	"	"	81·67	"
80·78	"	"	81·78	"

Curiously enough, Euler's corrected figures, as given here, are still affected by trifling arithmetical errors of from one to four units in the second decimal place. The agreement of these results among themselves is no proof of the correctness of the process of analysis. The great variation between the average percentage of molybdenum trioxide in ammonium molybdate as found by Euler in a molybdate of known constitution and the percentage of the trioxide as found by Friedheim (if we understand Euler aright) may be due conceivably to either or both of two causes, viz: the change of material analyzed and the change of operator or conduct of the operation. We shall show in the following account of our work that the exact control of the conditions of treatment, along the lines laid down

* Ber. d. d. chem. Gesell., xxix, 2981.
† Gooch, this Journal IV, iii, 237.
‡ Zeit. f. Anorg. Chem., xv, 454.

formerly, is actually essential to the reduction of molybdic acid according to the theory of the process.

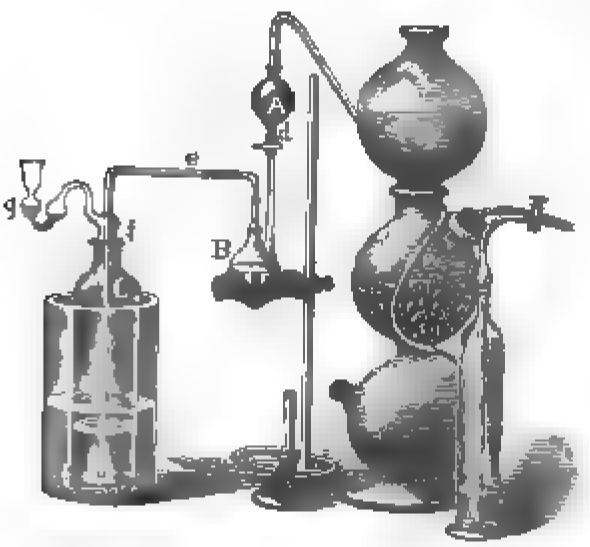
Our experiments were made with ammonium molybdate twice recrystallized from the presumably pure salt. The constitution of the preparation was determined by careful ignition *per se* and, for greater security, with sodium tungstate free from carbonate. It contained 81·83 per cent of molybdenum trioxide.

The potassium iodide which we used was prepared by acting with re-sublimed iodine upon iron wire, and precipitating by potassium carbonate—the proportions of iodine and iron having been adjusted to secure the formation of the hydrous magnetic oxide of iron. The filtrate from the iron hydroxide gave on evaporation and crystallization potassium iodide which was free from iodate.

The hydrochloric acid was taken of sp. gr. 1·12, because this is the strength used by Friedheim and Euler.

The sodium thiosulphate employed was taken in nearly decinormal solution, and was standardized by running it into an approximately decinormal solution of iodine which had been determined by comparison with decinormal arsenious acid made from carefully re-sublimed arsenious oxide. We chose this method of standardizing—the introduction of the thiosulphate into the iodine—rather than the reverse operation, in order that the conditions of the actual analysis might be followed in the standardization.

The distillation apparatus was constructed with sealed or ground joints of glass wherever contact with iodine was a possibility. It was made by sealing together a separating funnel A, a 100^{cm^3} Voit flask B, a Drexel wash-bottle C, and a bulbed trap *g*, as shown in the figure. Upon the side of the distillation-flask B was pasted a graduated scale by means of which the volume of the liquid within the flask might be known at any time. Carbon dioxide, generated in a Kipp apparatus by the action of dilute hydrochloric acid (carrying in solution cuprous chloride to take up free oxygen) upon marble previously boiled in water, was passed through the apparatus before and during the operation, so that it was possible to interrupt the process of boiling at any point of concentration, to remove the receiver by easy manipulation, to



replace the receiver, and to continue the distillation without danger of admitting air to the distillation flask.

In experiments to be described—(1) to (5) of the table—the proportions of potassium iodide and molybdic acid, and the strength of the hydrochloric acid recommended by Friedheim and Euler were retained. The essential change of condition is the removal of atmospheric air from the distillation flask before the acid is admitted to contact with the other reagents. Potassium iodide (3 grm.) and water (200^{cm^3}) were put into the receiver C, and a little of this solution was allowed to flow into the trap *g*. Ammonium molybdate carefully weighed (0·3 grm.) and potassium iodide (0·5 gm. to 0·75 grm.) were introduced into the distillation-flask B, the apparatus was connected as shown in the figure and carbon dioxide was passed freely through the whole apparatus for some minutes. The stop-cock *d*, between the bulb of the funnel A and the flask B, was closed and hydrochloric acid (40^{cm^3}, sp. gr. 1·12) was poured into the funnel; the air above the liquid in the funnel was displaced by carbon dioxide through the space between the neck of the funnel and the loosely adjusted stopper carrying the inlet tube; the connection between the funnel and inlet tube was tightened, the stop-cock opened, and the acid, under the pressure of carbon dioxide, was permitted to flow into the flask. In this way the acid, iodide and molybdate were made to interact with little danger of the presence of oxygen. The flask was heated by the Bunsen burner and the iodine evolved, passing over quietly in the slow current of carbon dioxide, collected in the receiver. The liquid was boiled until fumes of iodine were no longer visible above the liquid in the flask and connecting tubes backed by a ground of white, and then a full minute more. At this stage, the green color of the liquid having developed fully, the apparatus was permitted to cool, the current of carbon dioxide was increased, the cap of the receiver was loosened at *f*, the contents of the trap were washed back into the receiver, the rest of the apparatus was lifted bodily from the receiver, the liquid adhering to the inlet-tube was washed off into the receiver and the end of the tube was dipped immediately into a solution of potassium iodide. The constant flow of carbon dioxide prevented reflux of air during the transfer, and as soon as the end of the tube had been submerged in the solution of potassium iodide (which was employed not only as a water-seal, but to catch any iodine still carried in the gas), it was possible to reduce the rapidity of the current.

After titrating the iodine in the distillate the receiver was again placed in the train and the process of distillation was resumed under the former conditions and continued until the

volume of the liquid, as indicated upon the scale, had diminished to 25^{cm^3}, when the distillation was interrupted. The apparatus was manipulated as before to prevent access of air, and the iodine evolved in the second treatment determined. A third period of distillation served to show the iodine liberated during the concentration of the liquid from 25^{cm^3} to 10^{cm^3}.

A

	HCl Sp. gr. 1·12 taken.	KI in retort.	MoO_3 taken as ammonium molybdate.	MoO_3 corresponding to iodine found. 1st stage 40^{cm^3} to 32^{cm^3}. Green color.	2d stage 32^{cm^3} to 25^{cm^3}.	3d stage 25^{cm^3} to 10^{cm^3}
	cm^3	grm.	grm.	grm.	grm.	grm.
(1)	40	0·5	0·2455	0·2399	0·0076	0·0004
(2)	40	0·5	0·2455	0·2402	0·0053	0·0013
(3)	40	0·5	0·2455	0·2414	0·0040	0·0004
(4)	40	0·75	0·2455	0·2404	0·0061	0·0004
(5)	40	0·75	0·2455	0·2431	0·0037	0·0004
(6)	40	1·	0·2455	0·2404	0·0085	0·0019
(7)	40	2·	0·2455	------	-----	-----

B

	MoO_3 corresponding to iodine found during period of Friedheim and Euler. (1st stage.)	Error.	MoO_3 corresponding to iodine found in concentrating from 40^{cm^3} to 25^{cm^3}.	Error.	MoO_3 corresponding to iodine found in concentrating from 40^{cm^3} to 10^{cm^3}.	Error.
	grm.	grm.	grm.	grm.	grm.	grm.
(1)	0·2399	0·0056 −	0·2475	0·0020 +	0·2479	0·0024 +
(2)	0·2402	0·0053 −	0·2455	0·0000	0·2468	0·0013 +
(3)	0·2414	0·0041 −	0·2454	0·0001 −	0·2458	0·0003 +
(4)	0·2404	0·0051 −	0·2465	0·0010 +	0·2469	0·0014 +
(5)	0·2431	0·0024 −	0·2468	0·0013 +	0·2472	0·0017 +
(6)	0·2404	0·0051 −	0·2489	0·0034 +	0·2508	0·0053 +
(7)	------	------	------	------	0·2495	0·0040 +
					0·2529*	0·0074 +

* On repeating distillation with a fresh charge of acid.

During the first period of distillation the liquid assumed the clear green color, which changed but slightly until the beginning of the third period, when the tint verged upon olive, and

at the end of the operation the color of the liquid was an olive brown which grew browner on cooling. The addition of considerable hydrochloric acid to the residual liquid restored the clear green color, while water changed the olive brown to reddish yellow, the tint varying with the dilution. The results of these experiments are recorded in (1) to (5) of the accompanying table. In division A are given the weights of molybdenum trioxide corresponding to the amounts of iodine found in the three stages of distillation; in division B, the molybdenum trioxide corresponding to the iodine evolved from the beginning of the process to the end of each stage.

The mean error of the indications taken during the period of distillation advocated by Friedheim and Euler is 0·0045 grm.—;* that of the period of concentration from 40^{cm^3} to 25^{cm^3} is 0·0008 grm.+; and that of the full period of distillation is 0·0014+. It is plain beyond a peradventure that in the process as conducted by Friedheim and Euler, excepting the protection against atmospheric action, the theoretical reduction of the molybdic acid does not take place. The best results are obtained when the distillation is prolonged until the original volume of 40^{cm^3} has been diminished to 25^{cm^3}. Concentration beyond the limit of 25^{cm^3} tends to develop a tendency toward over-reduction, especially when the amount of potassium iodide is increased beyond about 0·5 grm. in excess of that theoretically required. This is shown in experiments (6) and (7), conducted otherwise similarly to those described above, in which the amount of potassium iodide was increased to 1 grm. and 2 grm. The error after distilling from 40^{cm^3} to 10^{cm^3}, the lowest limit of the preceding experiments, was 0·0053 grm.+ and 0·0040 grm.+, and the latter error was increased to 0·0074 grm.+ on repeating the distillation with a fresh portion (30^{cm^3}) of the acid. It is interesting to note incidentally that in the experiment in which the largest amount of iodide (2 grm.) was used the solution did not take the green color at any stage of the distillation, probably because the large excess of iodide held the free iodine and so masked the color until the degree of concentration was reached at which the olive brown color displaces the green.

The possibility of the interaction of atmospheric oxygen and gaseous hydriodic in the analytical process, even to the extent of producing errors of from one to three per cent reckoned as molybdenum trioxide, was recognized by Friedheim and Euler; and it was to obviate this difficulty that the recommendation was made by them to warm very gradually the distillation flask filled two-thirds with the mixture of iodide, molybdate

* Even this figure does not disclose the full error, which is partly counterbalanced, as will appear later, by the effect of oxygen dissolved in the acid used in the process.

and acid, and to raise the liquid to actual boiling only when the space above the liquid in the retort and in the connecting tube is filled as completely as possible with iodine vapor, while the liquid in the receiver begins to rise in the tube.

The action of atmospheric oxygen upon the solution of hydriodic acid must, however, be also taken into acconnt. It is a familiar fact that when a considerable excess of strong hydrochloric acid is allowed to act in contact with air upon potassium iodide (free from iodate) dissolved in a little water, the mixture is colored by free iodine. The amount of iodine liberated by atmospheric action is insignificant when the acid is very dilute, but is considerable when the acid is strong, and increases with time and rise in temperature, as shown in the experiments recorded in the accompanying table.

KI taken. grm.	Volume. cm^3.	Percentage of HCl in aqueous acid.	Time in minutes.	Temperature, Centigrade.	MoO_3 equivalent to iodine found. grm.	Remarks.
1	66	2	1	23°	none	
1	66	2	10	23°	0·0001	
1	66	24*	10	23°	0·0017	Diluted to 500^{cm^3} before titrating with $Na_2S_2O_3$
1	66	24*	4	From 23° to the boiling point	0·0067	
1	66	24*	10		0·0121	

Even the precaution to conduct the operation in an atmosphere of carbon dioxide does not eliminate all chance of error of this sort unless the liquid of the mixture—the hydrochloric acid—is free from air. The experiments of the following statement, which were conducted in the apparatus and manner previously described, show this point clearly. Thus, 40^{cm^3} of unboiled acid, sp. gr. 1·12, introduced enough air into the apparatus to cause an error of 0·0013 grm. reckoned in terms of molybdenum trioxide, while the iodine set free by the action of the residual acid of this experiment upon another gram of potassium iodide introduced without admission of air corresponded to only 0·0002 grm. in terms of molybdenum trioxide. The use of acid of sp. gr. 1·1, freshly boiled in the air, obviously reduces the error due to the unboiled acid, but even in this case the effect of included oxygen was not wholly obviated.

*This corresponds nearly to sp. gr. 1·12.

KI taken. grm.	Vol. cm³.	Percentage of HCl in aqueous acid.	Concentration by boiling cm³.	MoO_3 equivalent to iodine found. grm.	Remarks.
1	40	24	40–30	0·0013	Iodine determined in distillate.
			30–20	0·0002	1 grm. of KI added to retort at the beginning of the 2d stage.
1	40	20	40–25	0·0005	The acid taken, sp. gr. 1·1, was freshly boiled and introduced at once upon KI in retort in CO_2.

It is obvious that the procedure recommended by Friedheim and Euler can by no possibility eliminate the effect of atmospheric action upon the mixture of acid and iodide. The extent of such action must depend upon such conditions as the size of the apparatus, the time of exposure, the body of air above and dissolved in the liquid, and the rate of displacement of the air. How great the error due to atmospheric action actually was in the process as conducted by Friedheim and Euler we, of course, have no means of knowing. It is to be hoped, however, that it was sufficiently great to counterbalance that other inevitable error (of about five milligrams) which exists by reason of the incompleteness with which molybdic acid is reduced under the conditions which these investigators prescribe; for, the value of Euler's work upon the vanadiomolybdates rests upon the chance that these two very considerable and indisputable tendencies to error may have neutralized one another.

It has been shown clearly that our former criticism of the procedure of Friedheim and Euler is justified in every particular. We have no change to make in the recommendation made therein as to necessary modifications.

If the conditions seem difficult, there is an alternative in the method proposed in the former article*, according to which the molybdate is reduced by the acid and iodide in an Erlenmeyer beaker (trapped loosely by means of a short bulbed tube hung in the neck) and the molybdenum pentoxide, freed from iodine by boiling, is reoxidized by standard iodine in alkaline solution.

* This Jour. IV, ii. 156.

ART. XVII.—*Sölvsbergite and Tinguaite from Essex County, Mass.;* by HENRY S. WASHINGTON.

A VISIT to the Christiania Region made last summer, in company with other American and English geologists, under the guidance of Prof. W. C. Brögger, greatly added to an interest in the closely parallel region of igneous rocks of Essex Co., Massachusetts, which had been already awakened through several visits. A series of microscopical and chemical examinations was undertaken, with the aim of comparing the two regions. In the course of this several rocks were shown to be types of such peculiar interest that it was decided to publish their descriptions in advance of a more general paper on the subject.

Glaucophane-Sölvsbergite.—The only mention of rocks belonging here, which I can find, consists of brief notes by Shaler* based on observations by R. S. Tarr, who describes dikes 3, 182 and 184 as quartz and feldspar porphyries containing glaucophane in the groundmass. Rocks from all these have been collected, but the specimens most thoroughly examined came from dike 184,—or rather from No. 184a of his list of dikes (p. 593).

The dike occurs at Andrew's Point, the northeastern extremity of Cape Ann, cutting the granite and running into the sea. It averages about 4 feet in thickness, with a strike of N. 45° W. (Shaler) and vertical dip. The structure is schistose parallel to the walls (well brought out by weathering), and it is split by joint-planes almost at right angles to its length. These joint-planes coincide with a secondary system of planes cracking the granite on either side, in most cases passing uninterruptedly from one into the other, and it is evident that both were acted on by the forces producing these simultaneously. There is no evidence of contact action on the granite, but the dike rock becomes notably coarser-grained toward the center, though still remaining fine-grained. The dike rock also carries two or three small inclusions of the wall material, and sends off a few slender apophyses. There can be absolutely no doubt that it is a true dike of igneous origin.

The rock is rather dark, slightly bluish gray, fine-grained and compact, and splits quite readily parallel to the walls. No phenocrysts are visible. The specific gravity is 2·703 at 22° C.

Under the microscope the rock shows a holocrystalline, microgranitic structure. True flow structure is not marked, but the schistose character is rendered evident by long streaks

* Shaler, Geology of Cape Ann, 9th Ann. Rep. U. S. G. S., 609, 1889.

of blue hornblende crystals. The constituents are *alkali-feldspar*, *quartz* and *blue hornblende*, with accessory *titanite*, *cordierite*, *apatite*, and an undetermined mineral.

The *feldspar* and *quartz* form a typically microgranitic intergrowth, the former being far more abundant than the latter. Both are xenomorphic, only occasional roughly lath-like feldspars being visible. The feldspar shows often between crossed nicols the moiré appearance common in the anorthoclases. Carlsbad twins are rather common, and some multiple twinning lamellæ are to be observed. The feldspars are perfectly fresh and clear, and contain, like the quartz grains, scarcely any inclusions.

The *hornblende*, which is the most characteristic component, is scattered fairly uniformly through the rock, though there are areas relatively rich or poor in it. The arrangement in streaks has been already noted.

The hornblende grains do not show crystal planes and are irregular in shape, not acicular, as is generally the case with these species. Prismatic cleavage at about 124° is prominent. The color in ordinary light varies with the direction of the section; those cut perpendicular to $\dot{c}$ are greenish yellow, while those parallel are dark or lighter blue-gray.

The extinction-angle is small, measurements with a Bertrand's ocular varying from 4°–7°; probably the latter figure comes near the truth. Whether the extinction was positive or negative could not be determined owing to the absence of crystallographic planes. Pleochroism is very intense; parallel to $\dot{c}$ dark (almost opaque) blue gray, parallel to $\dot{b}$ the same or a little lighter, and parallel to $\dot{a}$ pale greenish yellow. The determination of the axes of elasticity was rendered difficult by the intense coloration of the mineral, but a large number of observations both with the mica plate and quartz wedge seemed to show that the axis of least elasticity $\mathfrak{c}$ lay nearest the vertical axis. The absorption formula then would be $\mathfrak{c} \gtrsim \mathfrak{b} > \mathfrak{a}$.

This determination, if correct, would indicate that the hornblende is glaucophane, and this view is sustained, as will be seen later, by the results of a chemical analysis of the rock, from which it appears that the hornblende is a mixture of ferrous glaucophane and riebeckite molecules in the ratio of 3 to 2.

Titanite occurs in colorless grains of fair size, with the usual characters, and calls for no special comment.

There also occur some very small, highly irregular grains of a clear, doubly refracting mineral, either colorless or very pale violet, in the latter case pleochroic to a scarcely noticeable extent. The refractive index is not high and the double

refraction small, and the grains might be mistaken for quartz were it not for the color. Although no pleochroic halos were seen, the mineral is referred to *cordierite*. It may possibly be a foreign inclusion, brought up from below, but this point cannot be settled.

There are also seen a number of small, slender, light yellowish needles, which extinguish parallel to their length, and in some cases are very faintly pleochroic, with the absorption $\epsilon > \omega$. These are apparently *apatite*, though small irregular flakes of a similarly appearing substance do not show the usual form of this mineral, and they may possibly be *rosenbuschite*, which is said to occur in North American nepheline-syenites.*

The results of a chemical analysis by the writer are given in No. I.

	I.	II.	III.	IV.	V.
SiO_2	64·28	62·70	64·92	64·33	64·21
TiO_2	0.50	0·92	....	trace	....
Al_2O_3	15·97	16·40	16·30	17·52	16·98
Fe_2O_3	2·91	3·34	3·62	3·06	6·69
FeO	3·18	2·35	0·84	0·94	....
MnO	trace	trace	0·40	0·35	....
MgO	0·03	0·79	0·22	0·34	0·18
CaO	0·85	0·95	1·20	0·56	0·49
BaO	none	....	....	....	....
Na_2O	7·28	7·13	6·62	7·30	5·13
K_2O	5·07	5·25	4·98	4·28	4·41
H_2O, 110°	....	....	....	0·04	....
H_2O, ignit.	0·20	0·70	0·50	0·95	1·00
P_2O_5	0·08	....	....	trace	....
	100·33	100·53	99·60	99·67	99·09

I. Glaucophane-Sölvsbergite. Dike 184. Andrew's Point, Cape Ann, Mass. H. S. Washington anal.

II. Katoforite-Sölvsbergite. Lougenthal, Norway. Brögger. Grorudite-Tinguaite Serie, 80. L. Schmelck anal.

III. Aegirite-Sölvsbergite, Sölvsberget, Gran, Norway. Brögger, op. cit., 78. L. Schmelck anal.

IV. Aegirite-Sölvsbergite (Acmite-Trachyte), Crazy Mountains, Montana. Wolff and Tarr, Bull. Mus. Comp. Zool., xvi, 232, 1893. W. H. Melville anal.

V. "Aegirite-Trachyte." Kühlsbrunnen, Siebengebirge. Cited in J. Roth, Gesteins analyse, 1861, 21. Bischof anal.

The chief characteristics are medium acidity, high alkalies, especially soda, rather high FeO, and low MgO and CaO. These characters are well expressed in the mineral composition, which, since the rock is holocrystalline and of simple composition, is readily calculated to be as follows :

* Rosenbusch, Mikr. Phys., i, 510, 1892.

	Ia.	IIa.	IIIa.
Glaucophane	13·8	---	----
Riebeckite	10·6	----	----
Hornblendes	----	14·7	....
Pyroxene (Aegirite)	----	2·5	15·5
Albite	39·0	51·	50·5
Orthoclase	29·8	30·	29·5
Quartz	4·3	0·7	4·5
Titanite	1·9	----	----
Cordierite	0·3	----	----
Apatite	0·3	----	----
Accessories	----	1·0	----

In this calculation the small amount of CaO is just sufficient satisfy TiO_2 and P_2O_5 to form titanite and apatite, and the ıce of MgO is used up in cordierite. It is evident therefore at the blue hornblende is not the lime-bearing arfvedsonite, d that the glaucophane molecule present is not the usual ıgnesian one. We therefore have to assume a glaucophane ɔlecule in which RO is entirely FeO, and on this basis the rnblende as a whole is represented by the formula Gl_3Rb_2. may be noted, *en passant*, that poverty in MgO is character- ic of all the rocks of the region so far analyzed; and in this nnection the occurrence of the rare, purely ferrous olivine, yalite, at Rockport* may be recalled.

In view of the close resemblance in chemical and miner- ɔgical composition, as well as genetic relationships, with the .vsbergite of Norway, the present rock must be classed with em, and may be distinguished specifically as a *Glaucophane- lvsbergite.* This group was first described as such by Brög- r in 1894 and embraces medium to fine-grained dike rocks mposed largely of alkali feldspar, with soda pyroxenes or da hornblendes, either without quartz or very poor in it, d consequently of medium acidity. Analyses of Brögger's lvsbergites are given in Nos. II and III and their comparison th I is instructive. II is of a hornblende (katoforite) sölvs- rgite and it is seen to be almost identical with I, the slightly wer SiO_2, and higher MgO being the only noteworthy dif- rences. III is of an aegirite-sölvsbergite and this also is ɔsely similar, the chief difference here being the considerably wer FeO as compared with our rock. This difference seems have determined the formation of ægirite rather than a soda rnblende, since we find the same features in the analysis of e so-called "acmite trachyte" of the Crazy Mts. given in ɔ. IV, a rock which is referred to the Sölvsbergites by ɔsenbusch.† The mineral composition of the Norwegian

* Penfield and Forbes, this Journal, IV, i, 129, 1896.
† Rosenbusch. Mikr. Phys., ii, 476, 1896.

sölvsbergites, as calculated by Brögger, is given in II*a* and III*a*, and they are seen to be poorer in dark minerals and richer in the albite molecule. The mineral composition of the rock represented in IV could not be satisfactorily calculated. An analysis by Bischof of the "aegirite-trachyte" of Kühlsbrunnen in the Siebengebirge is given in V, and is seen to be closely similar to the others, though the lack of separate determinations of Fe_2O_3 and FeO and its date (1852) render it less valuable than one might desire. It is chiefly of interest as an instance of rocks of practically the same chemical and mineralogical composition occurring in connection with magmas of quite diverse characters.

In connection with the above rock it may be mentioned that closely similar rocks occur in Shaler's dike 182 (south of 184), near Pigeon Cove, and from a dike near Bass Rocks, east of Gloucester. The rock of dike 3, at Magnolia, is of similar character, but is remarkable for the abundance of well crystallized phenocrysts of feldspar and quartz. Specimens were collected from these localities this summer, but too late for description in this paper.

The rocks described above are of interest in view of the increase in localities of blue hornblendes identified in recent years, and call attention to the fact that such hornblendes are by no means uncommon in the igneous rocks of Eastern Massachusetts, just as they are frequent in similar rocks of the Norway region.*

Mr. T. G. White has recently described† the well known granite of Quincy, Mass., and has found that it contains a blue hornblende which he refers to glaucophane. This occurrence seemed of such importance that an analysis was deemed desirable, and through his kindness, for which I express my hearty thanks, I was put in possession of a specimen collected by himself. The results of an analysis made by me are given below in No. I. It will be seen that, as compared with the analysis of the sölvsbergite the differences are chiefly those depending on the higher acidity, with the exception of the relative amounts of Fe_2O_3 and FeO, which determined the character of the hornblende.

The character of the rock admits of a very satisfactory calculation of the mineral composition, with the result given in I*a* below. From this it appears that while the composition in general is analogous to that of the sölvsbergite, yet that there are one or two differences of note. While the absolute and relative amounts of albite and orthoclase do not greatly differ, quartz, instead of being quite subordinate in amount, takes

* Cf. Brögger, op. cit., 186, and Zeit. Kryst., xvi, 411, 1890.
† T. G. White, Proc. Bost. Soc. Nat. Hist., xxviii, 128, 1897.

second place. The hornblende is considerably lower, and instead of glaucophane (ferrous also) predominating over the riebeckite molecule, the latter surpasses the former, its composition being expressed by the formula Rb_9Gl_2. It is hence essentially a riebeckite rather than a glaucophane.

	I.	II.	III.	IV.	V.
SiO_2	73·93	71·65	73·35	74·35	70·15
TiO_2	0·18	trace	....	....	0·65
Al_2O_3	12·29	13·04	14·38	8·73	10·60
Fe_2O_3	2·91	2·79	1·96	5·84	5·77
FeO	1·55	1·80	0·34	1·00	1·74
MnO	trace	trace	....	0·22	0·52
MgO	0·04	trace	0·09	0·07	0·35
CaO	0·31	trace	0·26	0·45	0·72
BaO	none	....	....	....	....
Na_2O	4·66	6·30	4·33	4·51	5·30
K_2O	4·63	3·98	5·66	3·96	4·09
H_2O	0·41	1·10	....	0·25	trace
	100·91	100·66	100·37	99·38	99·89

I. Granite, Hardwick Quarry, Quincy, Mass. H. S. Washington, anal. Sp. gr. 2·642 at 22° C.

II. Soda Granite, Houguatten, Norway, Brögger, Gror. Ting. Ser. 127. L. Schmelck, anal.

III. Paisanite, Paisano Pass, Texas, Osann, Tsch. Min. Pet. Mitth., xv, 439, 1895. Osann, anal.

IV. Grorudite, Varingskollen, Norway, Brögger, op. cit. 48. Särnström, anal.

V. Grorudite, Grussletten, Grorud, Norway, Brögger, op. cit. 48. V. Schmelck, anal.

	Ia.	*IIa.*	*IIIa.*	*IVa.*	*Va.*
Riebeckite	12·3	10·	6·	....	....
Glaucophane	2·0	4·	....	....	....
Ægirite	....	....	....	21·6	22·5
Albite	27·7	40·	32·	19·1	29·5
Orthoclase	27·2	23·	35·	21·8	24·5
Quartz	30·2	23·	27·	37·5	23·5
Accessories	0·6	....	....	....	0·5

In column II is given an analysis of a typical soda granite of Norway, which, according to Brögger is composed of alkali feldspar, quartz and blue hornblendes, with small amounts of magnetite, zircon, apatite, etc. It is closely parallel to our granite, the only differences of note being lower SiO_2 and correspondingly higher Na_2O. The results of a roughly approximate calculation based on Brögger's analysis and description are given in IIa, the hornblende being assumed from his de-

scription and the lack of CaO to be a mixture of riebeckite and glaucophane. Here also it much resembles the Quincy granite, though albite is higher and quartz and orthoclase lower. The hornblende is much the same in character and is of about the composition Rb_6Gl_2, the glaucophane here also being purely ferrous.

A comparison with the paisanite of Osann (III and III*a*) is also of interest. On the whole they are closely similar, though in paisanite the iron oxides, especially FeO, are lower and K_2O higher. Corresponding to this the mineral composition (calculated by Osann) shows rather more orthoclase, and the hornblende is almost a pure riebeckite containing only traces of glaucophane.

All the above calculations are of interest in pointing to the existence of a purely iron-alumina glaucophane.

Two analyses of grorudites given by Brögger are cited in IV and V, their mineral composition as calculated by Brögger being given in IV*a* and V*a*. These show, relatively toward the riebeckite granites and paisanite, much the same state of affairs which we remarked on in the sölvsbergites; in the aegirite-bearing grorudites Fe_2O_3 is much higher relatively to FeO. In the grorudites however Al_2O_3 is very considerably lower than in the others—facts which have been commented on by Brögger (op. cit. 128) and by Osann (op. cit. 441). The grorudites are much higher also in dark minerals.

It is to be seen from the above that from the classificatory standpoint, grorudite and sölvsbergite do not stand on precisely the same plane, the latter being broader than the former. The sölvsbergites include both soda-pyroxene and soda-hornblende rocks, the latter being distinguished from the former in nomenclature by the use of the name of the hornblende. The grorudites are essentially aegirite rocks, (katoforite and other soda-hornblendes occurring in subordinate amounts), while their hornblende-bearing equivalents are known as paisanite, the effusive form being the comendite of Bertolio.* This is, of course, a small matter, but significant of the present state of confusion in petrographical nomenclature and classification, and of the pressing need of some systematization.

Tinguaite.

Analcite-Tinguaite.—The rock which is here discussed forms a small dike cutting the granite of Pickard's Point, south of Singing Beach, at Manchester. It also cuts a wide dike of diabase, or rather labradorite-porphyrite, with large pheno-

* I follow Brögger (op. cit. 63–65) rather than Rosenbusch (op. cit. 614), who correlates the comendites with the paisanites and the grorudites with the pantellerites.

crysts of labradorite, some of which measure over 10^{cm} in length. The tinguaite was discovered by Mr. J. H. Sears of Salem, Mass., who described it in 1893.* It is also briefly noticed by Rosenbusch,† who speaks of it as "an eminently fresh and typical tinguaite, with rather greasy luster, and lighter in color than usual. The small, rare phenocrysts are microcline and microcline-microperthite. In the groundmass there appears to be present some analcite pseudomorphous after leucite."

Although the rock has been described by Sears, yet a description of the specimens in my possession will not be out of place, in view of certain features to be discussed later.

The rock is very compact, tough and aphanitic, with a silky sheen, and the slightly greasy luster common to the tinguaites. Its color is olive-green, varying somewhat in different specimens, from greenish gray to greenish black. A few white feldspar phenocrysts are visible. The specific gravity was determined by the balance to be 2·474 at 22° C.

In thin section the freshest specimens (obtained by Mr. Sears from blasting, and toward the center of the dike), show a structure characteristic of such rocks—needles and larger grains of aegirine, with many needles and a few phenocrysts of feldspar, lie in a clear, colorless groundmass, which in general is isotropic, but which here and there shows faint double refraction. The rock is *perfectly fresh*, no trace of decomposition being observed in any of the constituents. There are no evidences of flow structure.

The *aegirite* occurs as slender needles and as larger, generally elongated, crystal fragments. It is perfectly fresh and carries no inclusions, beyond an occasional minute speck. The extinction angle, measured on many sections which (as shown by the pleochroism) were approximately parallel to *b* (010), was found to be about 7°. The axis of elasticity lying nearest to $\dot{c}$ was determined by means of the mica plate to be $\mathfrak{a}$. Pleochroism is rather feeble; $\mathfrak{a}$ slightly bluish green, $\mathfrak{b}$ yellowish green, $\mathfrak{c}$ slightly brownish green to yellow. The difference of absorption was slight; $\mathfrak{c}$ about equal to $\mathfrak{a}$, and this slightly greater than $\mathfrak{b}$. Some of the larger crystals show cores of a brownish yellow, non-pleochroic pyroxene, but this is present in very small amount.

Only a few of the *feldspar* phenocrysts were visible in the sections. I could find no microcline twinning, and, as far as my observations go, judging chiefly from the moiré appearance,‡ they seem to be anorthoclase rather than microcline.

* J. H. Sears. Bull. Essex Institute, xxv. 4, 1893.
† Rosenbusch, Mikr. Phys., ii, 483, 1896.
‡ Cf. Pirsson, this Journal, ii, 196, 1896.

One case of Carlsbad twinning was seen, and here and there a microperthitic structure was very evident. The small feldspars of the groundmass are slender needles—probably of anorthoclase—elongated (as shown by use of the quartz wedge), parallel to $\grave{a}$. The extinction is either parallel or at very small angles.

A few very small, colorless crystals of high refractive index and double refraction, are supposed to be *zircon*. None of the sodalite spoken of by Sears could be seen, though the analysis shows that some of it is present. Magnetite is entirely absent.

The clear, colorless, micro-groundmass in which the above minerals lie is holocrystalline, and composed of *nepheline* and *analcite*. These form irregular areas of varying sizes, passing rather indefinitely from one into the other. Those of nepheline are distinguished by their faint double refraction, lack of cleavage, and by the fact that the index of refraction is, as shown by Becke's method, rather higher than that of the anorthoclase needles. One or two fair-sized crystals of nepheline were observed. The patches of analcite are readily distinguished by their cubic cleavage, exhibited by well-defined straight cracks crossing at right angles, by their generally isotropic character, and by the fact that their refractive index is notably lower than that of the feldspars. In places they show a very faint double refraction, analogous to that of leucite, but not as well marked. While the aegirite and feldspar needles are scattered through both, yet the analcite areas are rather poorer in them than those of nepheline. The areas of both, when treated with HCl, gelatinize easily and stain with fuchsine. It must be mentioned that on a first cursory examination the analcite was passed over as nepheline, and it was not until the H_2O determination of the analysis showed a percentage in striking contrast with the freshness of the rock that the presence of analcite was definitely determined.

The freshest specimens from near the borders of the dike show characters analogous to the preceding, though they are much finer-grained, and apt to be somewhat decomposed.

A chemical analysis was made on a specimen from near the center of the dike, obtained by blasting, this being far fresher than those collected by myself. For it, as well as for other material from this region, I am deeply indebted to the liberality of Mr. J. H. Sears. The results are given in No. I.

The analysis is seen to be that of an almost normal tinguaite; silica, iron oxides, magnesia and lime not varying materially from the figures of other analyses. Soda is, however, higher and potash very much lower than in any other, this rock being the poorest in K_2O of any tinguaite yet fully described. H_2O is high for a rock of the freshness of this one.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
SiO_2	56·75	56·58	55·65	53·21	54·07	54.46	58·70	58·64
TiO_2	0·30	....	....	0·35	0·15	trace	trace	0·20
ZrO_2	....	....	....	....	....	....	....	0·09
Al_2O_3	20·69	19·89	20·06	22.02	21·67	19·96	19·26	19·62
Fe_2O_3	3·52	3·18	3·45	4·18	3·55	2·34	3·37	2·17
FeO	0·59	0·56	1·25		....	3·33	0·58	0·42
MnO	trace	0·47	....	0·42	....	trace	0·10	0·20
MgO	0·11	0·13	0·78	0·91	0.36	0·61	0·76	0·37
CaO	0·37	1·10	1·45	1·33	0·36	2·12	1·41	1·24
BaO	none	....	....	....	....	....	....	trace
SrO	....	....	....	....	....	....	....	trace
Na_2O	11·45	10·72	8·99	10·37	8·91	8·68	8·55	8·39
K_2O	2·90	5·43	6·07	6·41	4·76	2·76	4·53	5·26
H_2O 110°—	0·04	....	....	....	....	....	0·07	0·34
H_2O 110°+	3·18	1·77	1·51	0·81	5·44	5·20	2·57	2·40
P_2O_5	....	....	....	....	....	....	0·10	0·03
SO_3	trace	....	....	....	....	....	....	trace
Cl	0·28	....	....	....	....	....	....	0.14
CO_2	....	....	....	....	....	....	....	0·23
	99·92	99·83	99·21	100·01	99·27	99·46	100·0	99·74

I. Tinguaite, Pickard's Point, Manchester, Mass. H. S. Washington, anal.

II. Tinguaite (dike border), Hedrum, Norway, Brögger, Gror. Ting. Ser. 113. G. Pajkull, anal.

III. Tinguaite (dike center), Hedrum, Norway, Brögger, Gror. Ting. Ser. 191. V. Schmelck, anal.

IV. Tinguaite Porphyry, Foia, Serra de Monchique, Portugal, Kraatz-Koschlau and Hackman, Tsch. Min. Pet. Mitth., xvi, 257, 1896. Mean of three poor analyses by students of Jannasch.

V. "Aegirite Tinguaite," Hot Springs, Ark., J. F. Williams, Ark. Geol. Surv., 1890, ii, 370. W. A. Noyes, anal.

VI. Tinguaite, Njurjawpachk. Umptek. Kola, Ramsay and Hackmann, Neph. Syen. Geb. Kola, Fennia 11. No. 2, 158, 1894. K. Kjellin, anal.

VII. "Acmite Trachyte," Crazy Mts., Mont., Wolff and Tarr, Bull. Mus. Comp. Zool., xvi, 232, 1893. W. H. Melville, anal.

VIII. Phonolite, Cripple Creek, Colorado, 16 Ann. Rep. U. S. G. S., ii, 39, 1895. W. F. Hillebrand, anal.

The rock which approaches closest to it is the tinguaite from the dike border at Hedrum, Norway (No. 2), the two being almost identical, except in K_2O and H_2O. Its relations to other tinguaites may be seen in the table, from which those very rich in potash are excluded.

The calculation of the mineralogical composition is somewhat uncertain, owing to the presence of three soda-alumina silicates, nepheline, albite and analcite, and ignorance of what amount of the H_2O present really belongs to the last. An attempt has been made in No. I*a*, which, though only very roughly approximate, corresponds fairly well with the rock as seen in thin sections. This calculation was subsequently checked by determination of the portion of the rock soluble in dilute HCl. The soluble portion amounted to 49·24 per cent of the whole. As the amount of nepheline and analcite was calculated to be jointly 48·3 per cent, and as a very small

amount of aegirine went into solution, the figures given in the table may be regarded as closely approximating to the truth. Sodalite is neglected in the calculation, as the Cl determination is thought to be much too high, and none was seen in the sections. II*a* and *b* are Brögger's calculations of the Hedrum tinguaite (op. cit. 115, 191). As far as pyroxene and orthoclase go the two correspond very well, but in the Massachusetts rock analcite largely replaces the albite and nepheline present in the other. IV*a* is the calculated composition of the Foia tinguaite (op. cit. 259).

	I*a*.	II*a*.	III*a*.	IV*a*.
Aegirine	10·2	15·	----	14·
Pyroxene	3·3	--	15·1	
Orthoclase	17·3	17·	20·3	26·
Albite	20·9	36·	29·8	19·
Nepheline	10·9	31·	29·9	21·
Analcite	37·4	--	----	--
Sodalite	----	--	----	18·
Accessories	----	1·	4·8	--

The occurrence of analcite in tinguaite is by no means new, Rosenbusch having noted it in our rock, Ramsay and Hackmann* in that of Umptek (No. VI), and Wolff and Tarr† in that of the Crazy Mountains (No. VII). In a section of the Hot Springs Tinguaite No. V (kindly given me by Prof. Pirsson) the groundmass is seen to be sprinkled with clear, isotropic patches, which may be nepheline cut basally or else analcite, the grain being too fine to show cleavage. The probabilities are that they are analcite, as the appearance of the section is too fresh to admit our attributing much of the 5·44 per cent H_2O to decomposition. It is a common constituent of the closely analogous phonolites of Cripple Creek described by Cross.‡ The authors of the first two papers, together with Rosenbusch, regard the analcite as pseudomorphous after leucite or some other mineral. Cross regards it as primary, when discussing his phonolites. The possibility of the primary character of analcite in certain rocks has been upheld by Lindgren§ and Iddings,‖ and in a recent extremely suggestive paper Pirsson¶ has conclusively shown that what has been thought to be glassy base in the monchiquites is in reality analcite, and has greatly strengthened the arguments in favor of the occurrence of primary analcite in other rocks. In the present case

* Ramsay and Hackmann, Fennia 11, No. 2, 157, 1894.
† Wolff and Tarr, Bull. Mus. Comp. Zoöl., xvi, 230, 1893.
‡ Cross, 16 Ann. Rep. U. S. G. S., Pt. II, 32, 36, 1895.
§ W. Lindgren, Proc. Cal. Acad. Sci. (2), iii, July, 1890.
‖ Iddings, Jour. Geol., i, 638, 1893.
¶ Pirsson, Jour. Geol., iv, 679, 1896.

the texture and composition of the tinguaite render the separation of the analcite for analysis a practical impossibility, so that its presence cannot be definitely proved as in the case of Lindgren's analcite-basalts and the monchiquites. But the chemical analysis of the rock, and the physical properties previously mentioned, leave little doubt on this point. In support of its primary character we must fall back upon the freshness of the rock and the general arguments advanced by Pirsson and Lindgren.

It would seem necessary therefore to recognize the occurrence of analcite as a constituent of the tinguaites by the use of the name *analcite-tinguaite*, and to this subgroup the tinguaites of Manchester, Umptek, Crazy Mountains and possibly Hot Springs and other localities belong.

Locust, N. J., June 29, 1898.

Art. XVIII.—*Note on the Occurrence of Native Lead with Roeblingite, Native Copper, and other minerals at Franklin Furnace, N. J.*; by Warren M. Foote.

Mining done some months ago in the Parker shaft, North Mine Hill, Franklin Furnace, N. J., at a depth of 800 feet, yielded along with the usual ores occasional traces of native copper.* With it occur a number of minerals including roeblingite;† this species is found rarely in white masses in a grey porcellanous substance; again, in balls or radial aggregations of minute prismatic crystals, their terminations presenting a velvet surface; also in brown and reddish masses.

From different sources were secured specimens coming from this vein. In examining them with a lens, I noted a dull and discolored substance occurring in thin flakes. Its lead color and high luster on a fresh surface, with its unusual sectility, softness and malleability, at once suggested native lead. A small piece was tested on charcoal. In the oxidizing flame it easily volatilized, and a yellow coating was deposited, which disappeared under the reducing flame. A grain of the metal was quickly dissolved in hot dilute nitric acid.

Four specimens were secured, and further search and inquiry proved the metal to have occurred most sparingly. In one the lead is found in exceedingly thin scales or films, filling the crevices of the earthy porcellanous mineral, which broke so that flat surfaces of the lead were exposed; with it is inti-

* J. E. Wolff, Proc. of the Am. Acad. of Arts and Sciences, vol. xxxiii, No. 23.
† This Jour., vol. iii, p. 413, S. L. Penfield.

mately associated similar scales of native copper. Another specimen, consisting of garnet and brownish roeblingite, exhibits two irregular masses of lead 1 to 2 mm. diameter; also scales of lead and a globular mass of the metal with a white crystalline coating, and intermingled with a mass of copper. With it occur minute tabular crystals of an undetermined mineral. A mass of axinite, willemite, garnet, phlogopite and a new brick-red, lead-iron-calcium silicate,* shows a vein of copper crystals. They are irregularly distorted dodecahedrons, and pass into rough bands, where traces of lead are discernible. The fourth specimen is a compact form of pale yellow resinous polyadelphite, showing minute nuggets and films of lead and copper. No traces of lead crystals were observed.

The finding of roeblingite and another lead silicate in this vein with native lead, presents an analogy to that recorded at the prominent locality of lead, Långban, Sweden. Here it is found with a mineral containing lead silicate, ganomalite. This double occurrence of the metal with its silicate perhaps offers a field for investigation.

Besides adding one more species to the list of a locality famous for the number and variety of its minerals, the discovery is of interest because of the doubt surrounding the reported finds of lead outside of Sweden.

July 13, 1898.

* S. L. Penfield and H. W. Foote, this Jour., vol. v, p. 289.

ART. XIX.—*On the Position of Helium, Argon and Krypton in the Scheme of Elements;** by WILLIAM CROOKES, F.R.S.

IT has been found difficult to give the elements argon and helium (and I think the same difficulty will exist in respect to the gas krypton) their proper place in the scheme of arrangement of the elements which we owe to the ingenuity and scientific acumen of Newlands, Mendeléef and others. Some years ago, carrying a little further Professor Emerson Reynold's idea of representing the scheme of elements by a zigzag line, I thought of projecting a scheme in three dimensional space, and exhibited at one of the meetings of the Chemical Society† a model illustrating my views. Since that time, I have rearranged the positions then assigned to some of the less known elements in accordance with later atomic weight determinations, and thereby made the curve more symmetrical.

Many of the elemental facts can be well explained by supposing the space projection of the scheme of elements to be a spiral. This curve is, however, inadmissible, inasmuch as the curve has to pass through a point neutral as to electricity and chemical energy twice in each cycle. We must therefore adopt some other figure. A figure-of-eight will foreshorten into a zigzag as well as a spiral, and it fulfils every condition of the problem. Such a figure will result from three very simple simultaneous motions. First, an oscillation to and fro (suppose east and west); secondly, an oscillation at right angles to the former (suppose north and south), and thirdly, a motion at right angles to these two (suppose downwards), which, in its simplest form, would be with unvarying velocity.

I take any arbitrary and convenient figure-of-eight, without reference to its exact nature; I divide each of the loops into eight equal parts, and then drop from these points ordinates corresponding to the atomic weights of the first cycle of elements. I have here a model representing this figure projected in space; in it the elements are supposed to follow one another at equal distances along the figure-of-eight spiral, a gap of one division being left at the point of crossing. The vertical height is divided into 240 equal parts on which the atomic weights are plotted, from H=1 to Ur=239·59. Each black disc represents an element, and is accurately on a level with its atomic weight on the vertical scale.

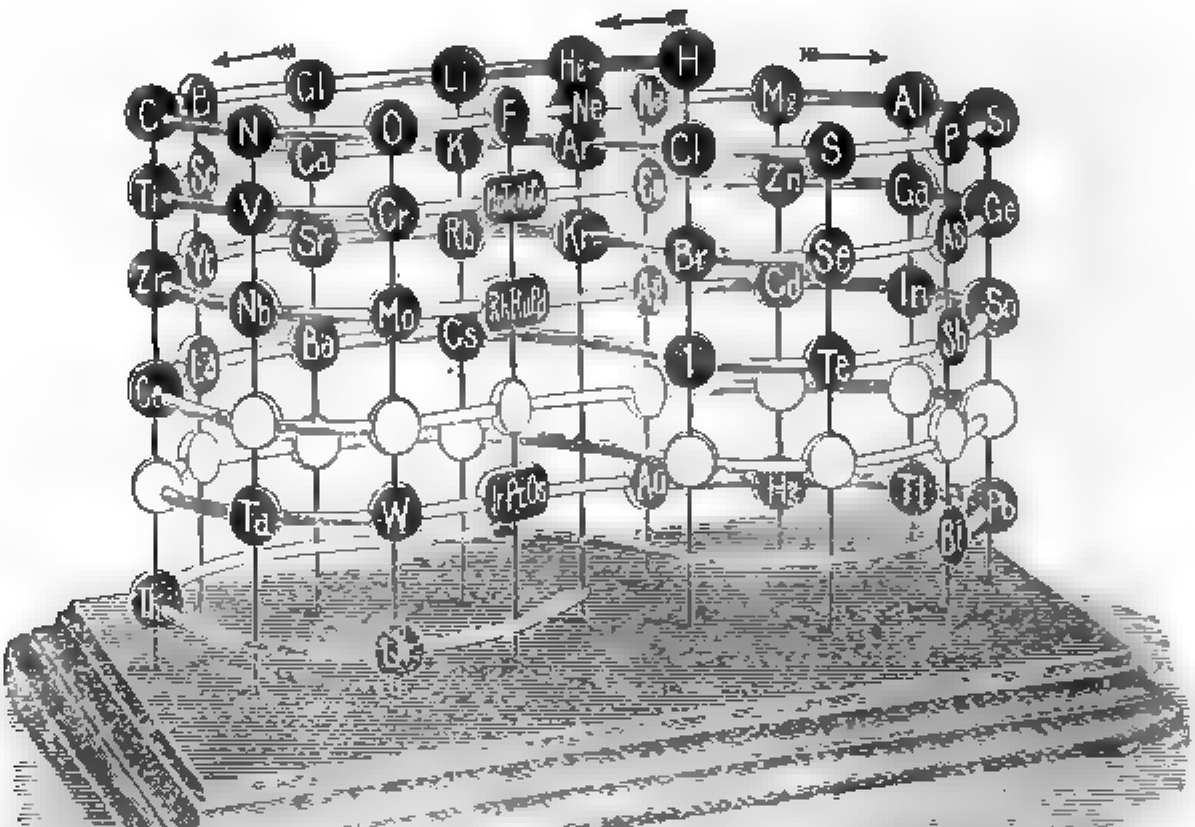
* Read before the Royal Society, June 9; from an advance proof sent by the author.

† Presidential Address to the Chemical Society, March 28, 1888.

The accompanying figure, photographed from the solid model, illustrates the proposed arrangement. The elements falling one under the other along each of the vertical ordinates, are

H	He	Li	Gl	B	C	N	O	F	Na	Mg	Al	Si	P	S
Cl	Ar	K	Ca	Sc	Ti	V	Cr	Mn·Fe·Ni Co	Cu	Zn	Ga	Ge	As	Se
Br	Kr	Rb	Sr	Yt	Zr	Nb	Mo	Rh Ru·Pd	Ag	Cd	In	Sn	Sb	Te
I	—	Cs	Ba	La	Ce	( )	( )	( )	( )	( )	( )	( )	( )	( )
( )	—	( )	( )	( )	( )	Ta	W	Ir·Pt·Os	Au	Hg	Tl	Pb	Bi	—
—	—	—	—	—	Th	—	Ur	—	—	—	—	—	—	—

The bracketed spaces between cerium and tantalum are probably occupied by elements of the didymium and erbium groups. Their chemical properties are not known with sufficient accuracy to enable their positions to be well defined. They all give colored absorption spectra and have atomic weights between these limits. Positions marked by a dash (—) are waiting for future discoverers to fill up.



Let me suppose that at the birth of the elements, as we now know them, the action of the *vis generatrix* might be diagrammatically represented by a journey to and fro in cycles along a figure-of-eight path, while simultaneously time is flowing on, and some circumstance by which the element-forming cause is conditioned (e. g., temperature) is declining; (variations which I have endeavored to represent by the downward slope.) The result of the first cycle may be represented in the diagram by

supposing that the unknown formative cause has scattered along its journey the groupings now called hydrogen, lithium, glucinum, boron, carbon, nitrogen, oxygen, fluorine, sodium, magnesium, aluminium, silicon, phosphorus, sulphur and chlorine. But the swing of the pendulum is not arrested at the end of the first round. It still proceeds on its journey, and had the conditions remained constant, the next elementary grouping generated would again be lithium, and the original cycle would eternally reappear, producing again and again the same fourteen elements. But the conditions are not quite the same. Those represented by the two mutually rectangular horizontal components of the motion (say chemical and electrical energy) are not materially modified; that to which the vertical component corresponds has lessened, and so, instead of lithium being repeated by lithium, the groupings which form the commencement of the second cycle are not lithium, but its lineal descendant, potassium.

It is seen that each coil of the lemniscate track crosses the neutral line at lower and lower points. This line is neutral as to electricity, and neutral as to chemical action. Electro-positive elements are generated on the northerly or retreating half of the swing, and electro-negative elements on the southerly or approaching half. Chemical atomicity is governed by distance from the central point of neutrality; monatomic elements being one remove from it, diatomic elements two removes, and so on. Paramagnetic elements congregate to the left of the neutral line, and diamagnetic elements to the right. With few exceptions, all the most metallic elements lie on the north.

Till recently chemists knew no element which had not more or less marked chemical properties, but now by the researches of Lord Rayleigh and Professor Ramsay, we are brought face to face with a group of bodies with apparently no chemical properties, forming an exception to the other chemical elements. I venture to suggest that these elements, helium, argon, and krypton in this scheme naturally fall into their places as they stand on the neutral line. Helium, with an atomic weight of 4, fits into the neutral position between hydrogen and lithium. Argon, with an atomic weight of about 40, as naturally falls into the neutral position between chlorine and potassium. While krypton with an atomic weight of about 80, will find a place between bromine and rubidium.

See how well the analogous elements follow one another in order: C, Ti, and Zr; N and V; Gl, Ca, Sr, and Ba; Li, K, Rb, and Cs; Cl, Br, and I; S, Se, and Te; Mg, Zn, Cd, and Hg; P, As, Sb, and Bi; Al, Ga, In, and Tl. The symmetry of these series shows that we are on the right track. It also shows how many missing elements are waiting for discovery,

and it would not now be impossible to emulate the brilliant feat of Mendeléef in the celebrated cases of Eka-silicon and Eka-aluminium. Along the neutral line alone are places for many more bodies, which will probably increase in density and atomic weight until we come to inert bodies in the solid form.

Four groups are seen under one another, each consisting of closely allied elements which Professor Mendeléef has relegated to his 8th family. They congregate around the atomic weight 57, manganese, iron, nickel and cobalt; round the atomic weight 103, ruthenium, rhodium, and palladium, while lower down round atomic weight 195 are congregated osmium, iridium and platinum. These groups are interperiodic because their atomic weights exclude them from the small periods into which the other elements fall; and because their chemical relations with some members of the neighboring groups show that they are interperiodic in the sense of being formed in transition stages.

Note, June 22d, 1898. Since the above was written Professor Ramsay and Mr. Travers have discovered two other inert gases accompanying argon in the atmosphere. These are called Neon and Metargon. From data supplied me by Professor Ramsay, it is probable that Neon has an atomic weight of about 22, which would bring it into the neutral position between fluorine and sodium. Metargon is said to have an atomic weight of about 40; if so, it shares the third neutral position with argon. I have marked the positions of these new elements on the diagram.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On a New Constituent of Atmospheric Air.*—On the 9th of June, Ramsay and Travers read a preliminary note before the Royal Society on the discovery of a new gas in the atmosphere. For this purpose about 750^{cc} of liquid air were allowed to evaporate slowly until only 10^{cc} remained. The gas from this was collected in a holder, and the oxygen was removed by copper and the nitrogen by a mixture of pure lime and magnesium dust. After sparking the residue in presence of oxygen and caustic soda $26 \cdot 2^{cc}$ of a gas remained, which showed feebly the spectrum of argon and in addition an entirely new spectrum. Though not completely separated from argon, the new spectrum was characterized by two very brilliant lines, one of which was closely coincident with D_3 and which rivaled it in brilliancy. Measurements with a grating of 14438 lines to the inch gave the following

values, all four lines being simultaneously visible: D_1 5895·0, D_2 5889·0, D_3 5875·9, D_4 5866·65; +1·7 to correct to vacuum. A green line was also seen comparable in intensity with the green helium line, of wave-length 5566·3, and a somewhat weaker green line 5557·3. Comparing simultaneously the spectrum of the new gas with that of argon, both in the spectrum of the first order, the wave-lengths of the lines of the new gas found in the violet were 4317, 4387, 4461, 4671; in the blue 4736, 4807, 4830, 4834, 4909; in the green 5557·3, 5566·3; in the yellow 5829, 5866·5; and in the orange 6011. By weighing the gas in a bulb of 32·321^{cc} capacity under a pressure of 521·85^{mm} and at 15·95°, its mass was found to be 0·04213 gram; which corresponds to a density of 22·47, that of oxygen being taken as 16. After sparking four hours with oxygen in presence of soda, the mass obtained was 0·04228, at 523·7^{mm} and 16·45°. This corresponds to a density of 22·51. The wave-length of sound in the gas was found to be 29·87, 30·13 in two cases, that in air being 34·17, 34·30, 34·57. Now since the square of the wave-length in air × its density: the square of the wave-length in the gas × its density:: the ratio of the two specific heats of air: this ratio for the gas, we have

$$(34{\cdot}33)^2 \times 14{\cdot}479 : (30)^2 \times 22{\cdot}47 :: 1{\cdot}408 : 1{\cdot}666.$$

From which it appears that the new gas, like argon and helium, is monatomic and therefore elementary. Whence the authors conclude that the atmosphere contains a new gas heavier than argon, and less volatile than nitrogen, oxygen or argon. It has a characteristic spectrum and the ratio of its specific heats leads to the inference that it is monatomic and hence an element. In case this conclusion is sustained they propose for it the name "*krypton*" or "concealed," with the symbol Kr. As to its position in the periodic arrangement, the authors conjecture that it may turn out to have a density of 40 with an atomic mass of 80, and so may belong to the helium series.—*Nature*, lviii, 127, June, 1898. G. F. B.

2. *On the Direct Elimination of Carbon Monoxide and on its Reaction with Water.*—It has been observed that when heated, certain organic compounds decompose and yield carbon monoxide directly and not as a reduction product of carbon dioxide. This reaction has been examined by ENGLER and GRIMM. Thus formic acid at 150°–160° gives gaseous products which contain 98·8 per cent carbon monoxide and 1·2 per cent carbon dioxide. Ethyl formate, which decomposes at 300°, yields a mixture composed of carbon monoxide 18·2, carbon dioxide 29·5, ethylene 7·2 and hydrogen 45·1 per cent. At the same temperature amyl formate decomposes similarly, but yields amylene in place of ethylene. Ethyl oxalate gives at 200° carbon monoxide 48·4, carbon dioxide 43·8 and 7·8 per cent of olefines. At 280° benzoin gives a gas which contains 92 per cent of carbon dioxide and 8 of the monoxide; an oily residue being also produced containing di-

phenylmethane, desoxybenzoin, benzil and as a decomposition-product, benzaldehyde. No gas is yielded by benzoylacetone at 300°. Carbon monoxide, pure and carefully freed from oxygen, does not react at 250° with water vapor, but does react at 300°, giving carbon dioxide. So that it seems probable that the formation of carbon dioxide in the various decompositions above mentioned is due to a secondary reaction between carbon monoxide, the primary product, and the vapor of water.—*Ber. Berl. Chem. Ges.*, xxx, 2921–2926, December, 1897. G. F. B.

3. *On Osmotic Pressure and Electrolytic Dissociation.*—The conclusion had been reached by TRAUBE some time ago that the contraction which takes place on the solution of a substance in water is proportional to the concentration of the solution, and is almost independent of the nature of the dissolved substance. This contraction has a value of about 13·5^{cc} for every dissolved gram-molecule of a non-electrolyte or for every dissolved gram-ion of an electrolyte. This contraction in aqueous solutions is conjectured to be due to the strong attraction between the solvent and the dissolved substance; and this suggests the hypothesis of a union (though a changing one) between the water and the substance which is dissolved. The number of water particles with which a given molecule of a substance in dilute solution combines, is equal for all non-electrolytes, and for dissolved electrolytes increases proportionally to the number of ions. From this fact, Van't Hoff's conclusion, that the osmotic pressure of a solution is equal to the pressure which the dissolved substance in the form of a gas would exert at that temperature, may be deduced. Use is made however, in this deduction, of the hypothesis that a molecule of any non-electrolyte in any dilute solution at any given moment is in union with only one particle of the solvent. The author shows that his views and those of Poynting accord better with observed facts than do the ordinary views of osmotic pressure. The following facts find in them their explanation: (1) Molecular weights vary, as determined in different solvents, (2) colloidal substances have an osmotic pressure equal to zero, or nearly so, (3) the course of any given reaction depends largely upon the nature of the solvent employed, as shown by Menschutkin, and (4) the fact of sugar inversion and analogous processes. Arrhenius's hypothesis of electrolytic dissociation is considered entirely superfluous. The view of the author is that in dilute solutions, of sodium chloride for example, one molecule of the salt is joined to two of water; while in concentrated solutions they are united one to one.—*Ber. Berl. Chem. Ges.*, xxxi, 154–159, February, 1898. G. F. B.

4. *On Fusion in the Electric Furnace.*—The effect produced by heating lime mixed with varying proportions of silica in the electric furnace has been investigated by ODDO. He used an alternating current of 120 amperes under a pressure of 40 volts. When granular lime alone was employed, which as is well known readily combines with water, a mass of crystalline scales was obtained which did not slake until after two or three days con-

tact with water. When a mixture of lime and silica in molecular proportions was heated in the electric furnace a crystalline mass of calcium metasilicate $CaSiO_3$ was obtained, which yielded gelatinous silica with hydrogen chloride and did not set when ground and mixed with water, either alone or mixed with lime. A mixture in the proportion of $(CaO)_2 : SiO_2$ is more refractory in the furnace, though it yields ultimately a compact crystalline mass of calcium orthosilicate Ca_2SiO_4, which placed in a dessicator, spontaneously disintegrates to a white amorphous powder. The salt itself gives gelatinous silica with hydrogen chloride and does not set with lime. When a mixture in the proportion of $(CaO)_3 : SiO_2$ is thus heated, a crystalline mass results which has the approximate composition $Ca_2SiO_4 . CaO$, and which disintegrates spontaneously like the orthosilicate, the result being a mixture of lime with the orthosilicate. This material also does not set with lime, and gives gelatinous silica with hydrogen chloride. Similar results are obtained when the CaO is to the SiO_4 as 6 is to 1. It appears therefore that whenever silica is heated with excess of lime combinations occurs only in the proportion needed to form orthosilicate.—*Real. Accad. Linc.* V., v, 361; *J. Ch. Soc.*, lxxiv, 219, May, 1898. G. F. B.

5. *On Ammonium Peroxide.*—In investigating peruranic acid, MELIKOFF and PISSARJEWSKI concluded that its salts were compounds of peruranic acid with metallic peroxides; and hence that the hydrogen ammonium salt must contain ammonium peroxide. When a concentrated ethereal solution of hydrogen peroxide cooled to $-20°$ is made to act on an ethereal solution of ammonia equally cooled, a heavy viscous liquid separates, having a faint odor of ammonia, and being strongly alkaline. With potassium hydroxide it yields ammonia and potassium peroxide. It irritates the skin, producing white stains. When the ethereal solution is cooled in solid carbon dioxide, acicular leaflets separate having the composition $(NH_4)_2O_2 . (H_2O_2)_2 . (H_2O)_{10}$. A better yield is obtained when the ethereal mixture is placed in a freezing mixture of snow and calcium chloride. Crystals then separate having the composition $(NH_4)_2O_2 . H_2O_2 . H_2O$. They are unstable and deliquesce at the ordinary temperature, first yielding ammonia and hydrogen peroxide, and then evolving oxygen with a little ammonium nitrite. The crystals readily abstract carbon dioxide from the air. They dissolve in alcohol, less readily at $-30°$. With peruranic acid, they give $(NH_4)_2O_2 . (UO_4)_2$.—*Ber. Berl. Chem. Ges.*, xxx, 3144, January, 1898; xxxi, 152–154, February 1898. G. F. B.

6. *On the Molecular Masses of Inorganic Salts.*—Aided by four of his students, WERNER has determined the molecular masses of a number of inorganic salts by the rising of the boiling point of an organic solvent, selected so that no dissociation would be expected. Many nitrogen and sulphur compounds were found suitable as solvents, piperidine, pyridine, benzonitrile, methyl, sulphide and ethyl sulphide being actually employed, the inorganic salts experimented with being for the most part the halogen

compounds of silver, cadmium, tin, copper, mercury, lead, iron, zinc, cobalt, nickel and aluminum. Some of these salts were found to form additive compounds with piperidine, and in a few cases with the other solvents, as lead nitrate with pyridine, cuprous chloride and cadmium iodide with methyl sulphide and mercuric iodide with ethyl sulphide. By means of solutions of anthracene and diphenylamine, the molecular constant was obtained for each solvent, as follows: methyl sulphide 18·5, ethyl sulphide 32·3, pyridine 30·07, piperidine 28·4, benzonitrile 36·55. As a result most of the salts examined gave results which agreed with the normal molecular mass. Thus aluminum chloride gave figures agreeing with $AlCl_3$, the results being analogous for $FeCl_3$. Cobaltous chloride and bromide, stannous chloride and bromide, and lead nitrate are all monomolecular; i. e., contain bivalent metallic atoms. In the case of the cuprous salts however, anomalous results were obtained. Cuprous bromide in ethyl sulphide, for example, gave results corresponding to a molecular mass of 226, while in pyridine and in methyl sulphide, the value obtained corresponded with the molecular mass 140. Cuprous chloride gave in all solvents an elevation corresponding to 120 and cuprous cyanide one corresponding to the formula $Cu_2(CN)_2$. Hence the normal cuprous molecules are represented by the formula CuCl, etc. sometimes partially associated to Cu_2Cl_2. Since this result may also be explained by dissociation of the more complex molecules, conductivity determinations were made, the results of which indicated the absence of metallic ions. The silver haloids showed a similar tendency to polymerize, giving double and even treble molecules; confirming the author's views of the cuprous salts.—*Zeitschr. Anorg. Chem.*, xv, 1–41, May, 1897.

G. F. B.

7. *On Sodium Carbide.*—The properties of sodium carbide have been further studied by MATIGNON. It is a white solid of density 1·575 grams at 15°, insoluble in all solvents. Though endothermic it is not exploded by a shock or by friction. At ordinary temperatures, it is unacted on by air or oxygen if dry, but when heated gently it becomes incandescent and is converted into carbonate. In chlorine it burns evolving carbon; iodine converts it into C_2I_4, fusing at 185°. Water decomposes it violently, setting free carbon: but added very gradually converts it into acetylene-sodium hydroxide. Sodium carbide burns in hydrogen chloride, producing sodium chloride and evolving hydrogen and carbon. But if suspended in ether, it is completely converted into acetylene and sodium chloride. It becomes incandescent in CO_2 or SO_2, liberating carbon. Carbon monoxide does not act on it below 250°, nor hydrogen sulphide below 150°. Nitrous and nitric oxides attack it, the former at 270°, the latter at 150°, with incandescence, yielding carbon and sodium carbonate. Mixtures with oxidizing agents are very sensitive to shock. Alkyl iodides and bromides act on it at 180°, yielding symmetrical acetylenes RC ⋮ CR. It is a much more active salt than calcium carbide, and its reactions are almost always violent.—*C. R.*, cxxv, 1033–1035, December, 1897. G. F. B.

II. Geology and Mineralogy.

1. *Cycad Horizons in the Rocky Mountain Region;* by O. C. Marsh.—After the article on the Jurassic Formation in this number of the Journal (pp. 105–115) was in print, I received some information about Cycad horizons in Wyoming, that bore directly on the question I discussed near the end of my paper. This information was of so much interest that I added a foot-note on p. 115, to place on record the important discovery by W. H. Reed, of two new Cycad localities in the Jurassic of Wyoming, both much farther west, and quite distinct from those already known around the Black Hills. One is in the Freeze Out Hills of Carbon County, and the other near the Wind River range.

Mr. Reed has since sent me a more complete account of the first of these localities, with a sketch showing the section of the strata where the Cycads were found, and also measurements of the successive strata exposed, from the Trias up to the so-called Dakota sandstone, that caps the bluff at that point. The marine Baptanodon beds here show a thickness of thirty-five feet. Above these is a series of fresh-water sandstones and shales, sixty-six feet in thickness, which in places contain remains of Laosaurus, a typical Jurassic Dinosaur. Immediately above these the Cycads occur in a narrow layer of white sandstone, and with them are various fragments of bones. Next above are fifty-five feet of strata containing vertebrate fossils, apparently indicating the Atlantosaurus beds. Above these are thirty feet of barren clays, and over all is the sandstone regarded as Dakota.

Mr. Reed has also sent me specimens of the Cycads found at this locality. As he has had an experience of twenty years or more on the Jurassic of the West, and is otherwise admirably qualified to judge of such horizons, his opinion is entitled to great weight, and should settle the question for this locality.

Mr. H. F. Wells, who has carefully explored the Black Hills Cycad horizon, and sent to the Yale Museum over one hundred specimens of these fossils, has also, at my request, sent me a sketch of a section near Blackhawk on the eastern rim of the Hills, a region which I have myself examined, although not recently. This section indicates that the Cycad horizon there is also in the Jurassic, and not in the Dakota, and this is borne out by other localities in the same vicinity.

Prof. L. F. Ward has published sections examined by him on the southwestern border of the Black Hills in 1893. He found no Cycads actually in place, but decided that the horizon in which they occur is Cretaceous.* I have recently placed in his hands for description all the western Cycads in the Yale Museum. Our views, however, do not at present coincide as to the age of the strata containing them, but the new facts which are now being brought to light will, I trust, soon place this matter beyond reasonable doubt.

Yale University, July 18, 1898.

* Journal of Geology, Vol. II, p. 250, 1894.

2. *Calamaria of the Dresden Museum.*—Professor H. B. GEINITZ, at the close of fifty-one years of active service as Director of the Dresden Museum, has contributed* a valuable revision of fossil Calamaria, adding some new forms, and perfecting the lists already published, by reconsideration of the nomenclature and reference to the bibliographical references up to the date of publishing. The report includes three *Archæocalamites* from the Culm. From the productive Coal Measures are reported 8 species of *Calamites*, 3 of *Calamitina*, 5 of *Asterophyllites*, 2 *Annularia*, 8 *Sphenophyllum*.

The Rothliegendes or Dyas furnishes eight representatives of *Calamodendron* which the author distributes in the genera *Calamites*, *Asterophyllites*, *Annularia* and *Sphenophyllum*.

H. S. W.

3. *Fossil Cephalopoda of the British Museum.*—Mr. G. C. CRICK, of the Geological Department, has prepared, and the British Museum trustees published, a complete list of the types and figured specimens of Fossil Cephalopoda in the Museum.† Each specimen is entered under the name given it when first figured or described, and additional reference is made to names subsequently applied. The entries are made in alphabetical order of genera. The Index is made alphabetical for species.

H. S. W.

4. *Two new fossils from Canada.*—Prof. J. F. WHITEAVES describes, in the Canadian Record of Science for October, 1897, two interesting fossils. *Actinosepia Canadensis*‡ is represented by a sepiostaire closely resembling that of the modern Sepia, but presenting generic differences from the Montana or Pierre-Fox Hills formation, at South Saskatchewan, opposite the mouth of Swift Current creek. The second§ is a tooth allied to *Holoptychius*, from the Upper Arisaig Series at McDonald's Brook, near Arisaig, N. S., supposed to be of the age of the Lower Helderberg, of the New York series. The specimen is provisionally referred to the genus *Dendrodus*, under the name *Dendrodus Arisaigensis*. H. S. W.

5. *Brief notices of some recently described minerals.*—MIERSITE is the name given by L. J. Spencer to a new form of silver iodide crystallizing in the isometric system. It is thus dimorphous with the well-known iodyrite which belongs to the hemimorphic group of the hexagonal system. Miersite has been observed in cubic crystals, showing faces of one or both of the tetrahedrons. It

* Die Calamarien der Steinkohlenformation und des Rothliegenden im Dresdener Museum. Beiträge zur Systematik, von H. B. Geinitz. Mittheilungen aus dem König. Min.-Geol. u. prähistorischen Museum in Dresden, vol. xiv, pp. 1–28, taf. I, 1898.

† List of the types and figured specimens of Fossil Cephalopoda in the British Museum (Natural History); by C. G. Crick; pp. 1–103. London, 1898.

‡ On some remains of a sepia-like cuttle fish from the Cretaceous rocks of the South Saskatchewan. Can. Rec. Sci. (October, 1897), pp. 459–461, pl. II.

§ Note on a first tooth from the Upper Arisaig Series of Nova Scotia; by J. F. Whiteaves. Can. Rec. Sci. (October, 1897), pp. 461–2.

has perfect dodecahedral cleavage and a pale or bright yellow color with adamantine luster. The locality is the Broken Hill silver mines of New South Wales. It is named after Prof. Henry A. Miers of Oxford.—*Nature*, April 14.

KALGOORLITE is a telluride of gold, silver and mercury described by E. F. Pittman from the telluride deposits of Kalgoorlie, West Australia. It occurs in massive form with subconchoidal fracture and iron-black color; specific gravity 8·791. An analysis by J. C. H. Mingaye gave the following results:

Te	S	Au	Ag	Hg	Cu
[37·26]	0·13	20·72	30 98	10·86	0·05 = 100

For this the formula $HgAu_2Ag_6Fe_6$ is calculated. Associated with kalgoorlite is a yellow telluride of gold (Te 56·65, Au 41·76, Ag 0·80) with sp. gravity = 9·377. This is referred to calaverite. —*Records of the Geol. Surv. of New South Wales*, vol. v.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *American Association for the Advancement of Science.*—A pamphlet giving the preliminary announcements in regard to the Boston meeting of the Association has recently been issued. This meeting is to be held August 22d to 29th and will be a notable one in the history of the Association since it marks its fiftieth anniversary. The offices of the Association, the General Sessions, and the sessions of the different sections and of the affiliated societies will be accommodated in the buildings of the Massachusetts Institute of Technology, or in those of the Boston Society of Natural History and the Harvard University Medical School near by. The headquarters of the Association will be in the Rogers Building, while the hotel headquarters of the Council will be at the Copley Square Hotel, corner of Exeter street and Huntington avenue. The local Secretary, Prof. H. W. Tyler, of the Institute of Technology, has charge of matters referring to transportation, hotel accommodation, etc., and should be addressed on these subjects. The Permanent Secretary is Mr. L. O. Howard of the Department of Agriculture, Washington.

The first general session will be held at 10 A. M. on Monday, August 22d, when the meeting will be called to order by the retiring President, Professor Wolcott Gibbs, who will introduce the President-elect, Professor F. W. Putnam. Prof. Gibbs will deliver an address the same evening on "Some Points in Theoretical Chemistry." Wednesday, August 24, is appointed for an excursion to Salem, and Friday for one to Cambridge and Harvard University. Longer excursions to the White Mountains, Cape Cod, Plymouth, Wood's Holl, Newport, etc., will be begun on Monday, August 29.

2. *Harper's Scientific Memoir.*—It is announced by Messrs. Harper and Brothers that they will soon begin the publication of a series of translations and reprints of various scientific memoirs not readily accessible to the general student. Professor Joseph

S. Ames of Baltimore will act as general editor, and a list of twenty-two names is given of gentlemen who are to take an active part in the different departments. The series will be in general more or less similar to *Ostwald's Klassiker der exakten Wissenschaften* (Engelmann, Leipzig) often referred to in these pages; like this it will consist of thin octavo volumes, at once convenient for reference and inexpensive. Volumes I and II now in press, both edited by Professor Ames, are as follows :

I. Memoirs by Gay-Lussac, Joule, and Joule and Thomson on the Free Expansion of Gases.

II. Fraunhofer's Papers on Prismatic and Diffraction Spectra.

A number of other volumes are stated to be in course of preparation.

3. *Electro-Mechanical Series: Industrial Electricity.* Translated and adapted from the French of HENRY DE GRAFFIGNY and edited by A. G. ELLIOTT, B.Sc. 152 pp., 12mo. London and New York, 1898 (Whittaker & Co.)—In its original French form, this little volume and the others of the series have had much success, and it may fairly be assumed that they will have a similar reception among English readers. The present volume is preliminary and general in its character and the treatment of the different subjects is necessarily brief, since only one hundred and fifty pages are given to the whole from the nature of electricity to the telegraph. The other volumes in preparation which are soon to follow will take up separate topics in some detail.

4. *A Catalogue of Earthquakes on the Pacific Coast: 1769 to 1897.* (253 pp.) By EDWARD S. HOLDEN, LL.D. Smithsonian Miscellaneous Collections 1087. Washington, 1898.—This volume is a reprint and extension of the pamphlet on the same subject issued in 1887. It gives a complete account of the earthquake observations made at Mt. Hamilton during 1887–1897, together with an abstract of the large mass of information which has been collected from many sources regarding the Pacific coast earthquakes during this period. The Lick observatory was equipped with a set of Prof. Ewing's instruments in 1887 and in 1888 began its active work of registering earthquake shocks and in collecting material in regard to them.

5. *Ostwald's Klassiker der Exacten Wissenschaften.* Leipzig, 1898. (W. Engelmann.) The following volumes in this valuable series have recently been published.

Nr. 93. Drei Abhandlungen über Kartenprojection von Leonhard Euler. (1777.) 77 pp.

Nr. 94. Ueber das Verhältniss zwischen der chemischen Zusammensetzung und der Krystallform arseniksaurer und phosphorsaurer Salze. (Uebersetzt aus dem Swedischen.) Von Eilhard Mitscherlich. (1821.) 59 pp.

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ART. XX.—*The Transition Temperature of Sodic Sulphate, a New Fixed Point in Thermometry*; by THEODORE WILLIAM RICHARDS.

I. *On the Constancy of the Point in Question.*

With the assistance of JESSE BRIGGS CHURCHILL.

ACCORDING to the Phase Rule of Willard Gibbs, in order to obtain a nonvariant point in any system two more conditions must be definitely fixed than the number of components in the system. In other words, if the system contains only one component, three conditions must be fixed; if two components, four conditions, and so on. Since such a nonvariant* point is invariable in temperature, as well as in every other respect, there evidently exist a great number of definite temperatures obtainable by the combinations of different substances.

Of these multitudinous nonvariant points, the world uses only two, the simplest possible, as the standards of thermometry. The fixed conditions are:—a definite pressure, and two phases of one component, water. While undoubtedly 0° and 100° Centigrade will always remain the standards of reference, it would be extremely convenient to have at least one definitely determined point between these. Many thermometers do not cover this whole range, and all are noticeably upset as to their internal condition by such wide variations of temperature.

Landolt's very carefully made determinations of the melting

* Trevor's term "nonvariant" is a peculiarly happy selection. His similar terms "monovariant," etc, would be equally suitable if they were not hybrids of Greek and Latin. Would it not be well to use instead of these the homogenous words "univariant," "bivariant," etc.? These latter terms are not likely to cause trouble because of their similarity to "univalent," etc., for both the numbers of syllables and the accents are different in the two series.

points of a number of organic substances* showed that these bodies are too much subject to contamination with clinging impurities to serve as accurate standards. Organic compounds are too plentiful in number to make the easy obtaining of any one alone an easy matter, and among inorganic substances no single suitable substance beside water seems to exist.

There is no reason, however, why we should be confined to the use of a single component in this search for fixed points. Two components, requiring four fixed conditions, should answer equally well. The only essential is that the substance involved should form perfectly definite phases, and should be capable of being obtained in the pure state. Nernst has suggested the use of "cryohydric" points as a means of maintaining constant low temperatures, but the possibility of utilizing higher nonvariant points involving two components as a basis of thermometry and a means of maintaining constant temperature does not seem to have been generally realized.

Of the many pairs of substances which might serve the purpose in view, the pair, sodic sulphate and water, seems to be the most suitable for several reasons.

In the first place, the system (Na_2SO_4. + $Na_2SO_4.10H_2O$ + saturated solution + vapor) is in equilibrium at 32·5°†—a most convenient point, less above ordinary temperatures than 0° is below them, and within the field of even very large-bulbed thermometers. This small elevation involves very little disturbance in the tension of the glass, as well as very slight correction on account of the column projecting into the cooler atmosphere of the room. Moreover 32·5° is near the temperature of greatest difference between the hydrogen and the mercury thermometer.

On the other hand, sodic sulphate does not "melt" so easily as to cause any difficulty in keeping it unfused in a reasonably warm place. A substance melting only a few degrees lower would be continually freezing into a solid lump, which could be extracted from its bottle only by melting. The fact that it is not deliquescent is also of value.

A much more important advantage, as far as exactness is concerned, is to be found in the great ease with which the substance may be obtained in a pure state. Its solubility is far less at 10° than it is at 33°, hence its recrystallization by cooling does not involve much loss. Moreover, it may also be crystallized in the anhydrous state by simply melting the aqueous crystals, and since this process necessarily brings into play a wholly new set of isomorphous relations, it may be relied upon to eliminate impurities which are not rejected by the hydrated crystals.

* Zeitschr. phys. Chem., iv, 349 (1889).

† Lowenherz found 32·39° (Zeitschr. phys. Chem., xviii, 70).

Again, the "melting" absorbs enough heat to insure the rendering "latent" of any heat evolved by the mechanical process of gentle agitation, or of any heat taken in from the environment. The semi-opaque nature of the mixture removes any serious danger from radiant heat.

Since the volume scarcely changes with the transition, reasonable alterations in pressure do not cause any essential change in the temperature. This fact may be of importance if one has occasion to use very deep layers of the mixture.

The number of possible hydrates is smaller in this case than in many, hence the change is a sharp one. The salt $Na_2SO_4.7H_2O$ is so soluble that it cannot exist in the presence of either of the other solid phases.*

Last, but not least, Glauber's salt is extremely inexpensive, and at hand in every chemical and physical laboratory. Oddly enough, the melting point of the anhydrous salt, 865°, is one of the most satisfactory standards among high nonvariant temperatures.

It is needless to state that the usual precautions necessary to obtain accurate results were taken in the thermometric work which follows, as well as in the chemical preparation. Several thermometers were used in the course of the experiments; they will be described as the account progresses. For the first determinations, which were wholly of a relative nature, a Beckmann thermometer of the first quality, made by Goetze of Leipzig, was chosen. This instrument was graduated to hundredths of a degree, and could be easily read to within a thousandth. Because of the thinness of its bulb, this thermometer was especially sensitive to pressure; hence it was guarded carefully during its use. It was always read in a vertical position, as were all the other thermometers. Since the temperature of the room remained essentially constant during the preliminary experiments, the barometric pressure did not change by important amounts, and the height of the mixture around the bulb was always about the same, the readings are directly comparable with one another without correction.

First Problem—The effect of the Temperature of the Environment.

At first sodic sulphate prepared by crystallizing twice in a porcelain dish the ordinary "purissimum" material of commerce was used. This preparation was coarsely powdered and

*The non-existence of the substance $Na_2SO_4.H_2O$ may now be considered proved. Even if it really exists, however, the facts recorded below remain; one must merely read "monohydrated" instead of "anhydrous," and the theory will be unchanged. See de Coppet, Berichte d. d. Ch. Gesell., xii, 248; also, Lescoeur, Ann. Chim. Phys. [6], xxi, 526 (1890).

partly dried in a desiccator. When placed in a wide test-tube surrounded by a Beckmann air-jacket (a still wider test-tube) and allowed to remain for an hour in a thermostat at 32·9°, it melted with absolute constancy at a temperature indicated on the arbitrary scale by 4·758. On the following day, upon being replaced in the thermostat the "melting" point appeared to be precisely the same. It was found advantageous to melt the crystals partially into a pasty mass, by means of a gas-lamp, before immersing them in the thermostat, and the mass was stirred gently by a ring-shaped platinum stirrer. Upon raising the temperature of the bath to 36° not the least change was observed, although this application of a higher temperature was allowed to continue for half an hour. A lower temperature, on the other hand, had a less satisfactory effect. When the bath was kept at 29° the thermometer in the sodic sulphate indicated a constant reading of 4·746, a depression of 0·012°. In order to verify this phenomenon, a purer specimen, which melted at 4·760° with the bath about 33°, was surrounded by an environment at 30°, and then indicated 4·750° on the arbitrary scale.

Thus it is evident that the most satisfactory results are to be obtained by melting the salt slowly, and not by allowing it to solidify. The reason for this is obvious. The anhydrous salt is far less apt to form supersaturated solutions than the hydrated salt, and the crystals instantly melt upon being heated above their transition point, absorbing an appreciable amount of heat in the process. On the other hand, in order that the mass may solidify, the anhydrous salt must dissolve while the supersaturated solution is depositing its hydrate, both of these operations being much less prompt than the preceding. In all subsequent determinations the thermostat was kept about half a degree above the point sought, and it was found that the mixture would then melt so slowly as to last for hours.

Second Problem—Concerning the Purity of the Salt Required.

Löwenherz* has found, under van't Hoff's direction, that an admixture of foreign substances lowers the transition temperature of sodic sulphate just as it does simpler melting points. Hence a study of the purification of the salt is of great importance for our present purpose.

The mother-substance used in preparing the salt above was found to melt at a temperature of 0·06° below that which had been twice recrystallized in porcelain. Four further crystallizations in platinum vessels changed the transition temperature only 0·002° above that corresponding to two recrystallizations, the arbitrary scale indicating 4·760°.

* Loc. cit.

While it seemed probable that this recrystallization had freed the salt from anything which could affect its melting point, further proof seemed proper. Hence a kilogram or so of pure sodic hydric carbonate was thoroughly washed with pure water, and was then dissolved in an excess of pure dilute sulphuric acid. After six crystallizations the salt was still perceptibly acid to methyl orange, and hence after testing the melting point the salt was recrystallized again, collected on a large Gooch crucible and washed. Although now free from any trace of acid, it was precipitated as anhydrous salt by heating to 100° (the mother liquor being rejected), redissolved at 33°, and recrystallized by cooling. These final operations were conducted with the purest water and all the precautions necessary in the most refined work. A portion of the later mother liquors was neutralized with pure soda and twice recrystallized in order to obtain a third sample.

Another thermometer was used in testing the melting points of these three samples. This thermometer, admirably made by Baudin of Paris in 1880, is graduated to the fiftieth part of a degree, and can be read by means of a telescope and micrometer to within a thousandth. Its scale is about forty centimeters long, and covering the twelve degrees between 21° and 33°, including the zero point below a small auxiliary bulb. This small bulb was always in the thermostat, leaving only about 10° of the column to be corrected for the lower temperature of the room. Following are the uncorrected results obtained with this thermometer:

The slightly acid salt melted at	32·520
The neutralized and recrystallized salt melted at	32·560
The purest, nine times recrystallized salt melted at	32·561
The twice recrystallized salt first made melted at	32·560

The last observation was made in order to compare this series with the other which has been made with the Beckmann thermometer. As the pressure had increased since the other readings were taken, the arbitrary thermometer itself could not be satisfactorily compared with that of French manufacture.

Evidently it is a matter of no great difficulty to obtain sodic sulphate of constant "melting point." Even two recrystallizations of the purest Glauber's salt of commerce carried on in porcelain vessels seemed to be enough to eliminate any serious impurity. In order to obtain certain results, the purification should be continued until the melting point is constant. The repeated recrystallization of the slightly acidified salt is especially instructive in this regard, for it is safe to conclude that when the acid has gone other accidental impurities would have disappeared also; and the methyl orange test is one of extreme delicacy if the solution is not too concentrated.

Third Problem—The Effect of Varying the Mass of the Phases.

Theoretically, of course, a change in the relative amount of the phases should cause no difference in the nonvariance of the point under consideration provided that no one phase totally disappears. But since the superficial area of either solid present is a factor in determining the speed of the adjustment of the equilibrium, it was thought that varying proportions might cause a slightly varying "temperature lag." Nevertheless, as a matter of fact, no reasonable increase in the amount of either of the solids or of the liquid seemed to cause the least effect, provided that the process was one of melting and not of solidifying, and the mixture was properly stirred. The Beckmann thermometer remained always at 4·760 as long as the barometer stood near to the normal height. In order to insure the rapid establishment of the equilibrium it was our custom to have always some anhydrous powder present in the first place. This precaution also renders harmless drops of water introduced on the washed thermometer or the stirrer. It is well to powder also the hydrated salt, or at least to use it in the form of fine crystals, so as to increase its surface.

Since the point in question seems then to fulfil all the requirements of an accurate standard of reference, manifestly its relations to the international standard should be established.

II. *Reference to the International Standard.*

The only good thermometers indicating 33° at hand in the chemical laboratory are two of a set (one of which has already been mentioned) made by Baudin, and these have not been accurately calibrated. On one occasion thermometer Baudin No. 9,389 indicated 32·570° as the point in question, and immediately afterward came to 0·097° in pure melting ice, a difference of 32·473°. Subsequently the same thermometer indicated a change of 32·560−0·086=32·474; while the other thermometer (No. 9,390) gave on two successive trials separated by perhaps a week 32·560−0·084=32·476 and 32·550−0·083=32·467. The mean of all these values is 32·472, and to this about 0·009* must be added to correct for the column of 10° exposed to the temperature of the room (about 26°). No other corrections are possible, and there is no further guarantee of the accuracy of the number 32·481° than the evident care used in the construction of the thermometers and the fact that they agree very closely. It is probable that the instruments were made to be used vertically, hence no correction to the horizontal position is needed.

* See tables by Rimbach in Landolt und Börnstein, page 143.

In order to decide more definitely the exact value, Professor Sabine was so kind as to bring from the Jefferson Physical Laboratory of Harvard University two of the admirable standards in use at that institution. These two instruments, the thermometers Nos. 11,142 and 11,143, of Tonnelot, have been subject to extremely minute scrutiny and calibration. They are of course accompanied by a very detailed report from the Bureau Internationale des Poids et des Mesures, and upon this are based all the corrections recorded below, except the last. This one, necessitated by the fact that the thermometers were not wholly immersed in the constant mixture, was calculated from the relative cubic expansion of glass and mercury. The length of the column exposed to the temperature of the room (25·5°) was estimated carefully with the help of another thermometer, and was found to be about 22° allowing for the conductivity of the glass and mercury. The correction, 0·024°, agrees closely with Rimbach's* empirical values, although his were not intended for such small corrections; probably it is not more than 0·003° in error.

Both thermometers are about six decimeters long, and have their hundred degrees divided into tenths. With the help of the accurate Geneva cathetometer employed, they could probably be read to within $\frac{1}{500}$°. The readings were made with the coöperation of Professor W. C. Sabine.

THE TRANSITION TEMPERATURE OF SODIC SULPHATE.

	Thermometer 11,142 Tonnelot.	Thermometer 11,143 Tonnelot.
Reading at transition point	+32·400	+32·498
Reading in melting ice	+ 0·120	+ 0·101
Uncorrected difference	+32·280	+32·397
Correction for calibration	+ 0·147	+ 0·028
" " interior press. (32°)	+ 0·0330	+ 0·0328
" " " " (0°)	− 0·0076	− 0·0075
" " exterior press. (32°)	− 0·0006	− 0·0006
" " " " (0°)	+ 0·0007	+ 0·0007
" size of divisions	+ 0·0104	+ 0·0059
" for projecting column	+ 0·024	+ 0·024
Transition point according to mean Parisian mercury thermometer	+32·487	+32·480

The purest sodic sulphate, and ice from water which had just been twice distilled in platinum (from permanganate, and then from a trace of acid potassic sulphate) were used, and the usual precautions of all kinds were taken. The readings were made with the thermometers vertical: they are reduced to the horizontal position above. The corrected barometer stood at 761^{mm} during the higher readings, and at 762·5 when the ther-

* *Rimbach*, loc. cit.

mometers were in ice. The middles of the bulbs were about 45^{mm} below the surface of the inverting mixture and about 37^{mm} under the ice water. The pressures corresponding are about 4·5^{mm} and 5·7^{mm} of mercury respectively. The sum total of the corrections for exterior pressure is wholly insignificant; they are included above only for the sake of completeness. One division of No. 11,142 equals 1·000320 standard mercury degrees, while one of No. 11,143 equals 1·000181 degrees.

The two results (32·487° and 32·480°) are probably as nearly equal as could be expected, considering that three of the four readings unfortunately fell on dividing lines.

The agreement of the average 32·484 with the result 32·481 obtained from Baudin's uncorrected instruments is notable; evidently the empirical graduation of the older day included a close approximation to most of the corrections. The result of Löwenherz, 32·39°, is the only previous value with which it is worth while to compare this, but his was meant only for relative work and was referred merely to "a normal thermometer" of uncertain origin.

While it would be unsafe to predict the precise limit of error of the final value 32·484 (or 32·379 referred to the hydrogen thermometer) the result is certainly near enough to the truth to be a great boon to those who have not a standard instrument at their disposal. If, as is usually the case, it is only desired to attain a result accurate to within $\frac{1}{100}$ degree, the thermostat is unnecessary. Surprisingly accurate results may be obtained in the ordinary Beckmann freezing-point apparatus, if the outer bath is a degree or two above the point desired.* In fact, it is really an easier point to use than either of the old points, for one can keep neither ice nor steam always at hand in a bottle. Probably the inversion temperature might be of great use as a means of maintaining large vessels at a perfectly constant temperature: this point deserves consideration. Moreover, while sodic sulphate has several advantages as a standard, there are undoubtedly many other substances which would also serve at other temperatures. One of these, calcic nitrate, inverting at about 42·7°, is at present under investigation at this laboratory, and it is hoped that a complete temperature-scale of standards may be established. It is also hoped that with an admirable new air-thermometer, at present nearly finished in the Jefferson Physical Laboratory, a direct determination of the transition temperature of sodic sulphate may be made in terms of the hydrogen standard.

In brief, this preliminary paper shows that sodic sulphate "melts" at almost exactly 32·48° according to the mean mercury thermometer, and that this temperature is so easily obtained and so constant as to be of great use in the future of thermometry and thermostatics.

Chemical Laboratory of Harvard College, June, 1898.

* For practical details, pp. 203–206 should be consulted.

ART. XXI.—*Distribution and Quantitative Occurrence of Vanadium and Molybdenum in Rocks of the United States*; by W. F. HILLEBRAND.

[Read before the Geological Society of Washington, D. C., May 25th.]

ASIDE from its well-known mineral combinations, vanadium has long been known to occur in magnetites and other iron ores. Hayes in 1875 reported its occurrence in a great variety of rocks and ores. Quoting from Thorpe's Dictionary of Chemistry "it is said to be diffused with titanium through all primitive granite rocks (Dieulafait) and has been found by Deville in bauxite, rutile, and many other minerals, and by Bechi and others in the ashes of plants and in argillaceous limestones, schists, and sands . . . . ." It is further reported to comprise as V_2O_5 ·02–·07 per cent of many French clays, ·02–·03 per cent of some basalts, ·24 per cent of a coal of unknown origin and ·45 per cent of one from Peru, amounting to 38·5 per cent and 38 per cent of the ash and noted respectively by Mourlot and Torrico y Meca. Doubtless many other instances of its occurrence have been noted.

In Table I following is shown its quantitative occurrence and distribution in a large number and variety of igneous rocks of the United States arranged according to their silica contents; and in Table II the same data are given for a few of the component minerals separated from some of those rocks, while Table III shows its presence in metamorphosed and secondary rocks by a few examples of roofing slates and schists and especially by two composite samples representing 253 sandstones and 498 building limestones. These last two afford positive proof of its general distribution through rocks of those classes. Incidentally some information has been acquired as to molybdenum. Owing to lack of entire certainty as to its condition of oxidation, the vanadium is tabulated in terms of both V_2O_5 and V_2O_3, a point which will be reverted to later on. With very few exceptions the amount of each sample taken for analysis was five grams. The reagents used were carefully tested and found free from vanadium and molybdenum. Except Nos. 38, 39, 47, 52, and 53, by Dr. H. N. Stokes, all determinations are by myself.

TABLE I. *Igneous Rocks.*

No.	Name and locality of occurrence.	SiO_2 %	V_2O_5 %	$=V_2O_3$ %	Mo %
1.	Melilite-nepheline basalt, Uvalde Co., Texas	38	·054	·045	
2.	Nephelinite, Uvalde Co., Texas	40	·042	·035	
3.	Saxonite, Douglas Co., Oregon	41·5	none	none	
4.	Diorite, Cecil Co., Maryland	44	·062	·052	none

No.	Name and locality of occurrence.	SiO_2 %	V_2O_5 %	$=V_2O_3$ %	Mo %
5.	Gabbro, Adirondack region, N. York	45	·02	·017	
6.	Plagioclase basalt, Uvalde Co., Texas	45	·048	·04	
7.	Amphibole gabbro, Alpine Co., Calif.	46	·046	·038	none
8.	Plagioclase gneiss, Amador Co., Calif.	46·5	·033	·027	
9.	Diorite, Mitchell Co., N. Carolina	47	·05	·042	
10.	Porphyry, La Plata Co., Colorado	47	·06*	·05*	
11.	Amphibole gabbro, Tuolumne Co., Calif.	47	·024	·02	none
12.	Orthoclase-bearing basalt, Uvalde Co., Texas	48?	·048	·04	
13.	Orthoclase-bearing basalt, Uvalde Co, Texas	48	·02	·017	
14.	Norite, Cecil Co., Maryland	48	·023	·019	
15.	Gabbro, Union Co., Tennessee	48	·038	·032	
16.	Gabbro, Douglas Isld., Alaska	48	·055	·046	none
17.	Nepheline basanite, Colfax Co., N. Mexico	48·5	·044	·037	
18.	Olivine basalt, Kruzoff Isld., Alaska	49·5	·054	·045	none
19.	Diabase, Mt. Ascutney, Vermont	49·5	·034	·028	
20.	Phonolite, Cripple Creek, Colorado	50	·033	·027	
21.	Syenite lamprophyre, Prowers Co., Colorado	50·5	·04	·033	
22.	Augite-andesite porphyry, Electric Peak, Wyoming	50·5	·045	·038	
23.	Pyroxenic gneiss, Calaveras Co., Calif.	51·5	·10	·083	none
24.	Labradorite porphyrite, Michigamme iron district, Michigan	52·5	·048	·04	
25.	Pyroxenite, Cecil Co., Maryland	53	·04	·034	none
26.	Orendite, Sweetwater Co., Wyoming	54	·022	·018	
27.	Andesite, El Paso Co., Colorado	54?	·018	·015	tr.?
28.	Nepheline syenite, El Paso Co., Colorado	54·5	·022	·018	tr.?
29.	Diorite, Butte and Plumas Cos., Calif.	54·5	·037	·031	none
30.	Quartz diorite, Cecil Co., Maryland	55	·043	·036	none
31.	Diorite, La Plata Co., Colorado	55·5	·038	·032	
32.	Camptonite? San Miguel Co., Colorado	55·5	lost, but considerable		
33.	Phonolite, Colfax Co, N. Mexico	56	tr.	tr.	
34.	Augite-bronzite andesite, Unga Isld., Alaska	56·5	·046	·038	none
35.	Andesite, El Paso Co., Colorado	57?	·025	·021	tr.?
36.	Spilosite, Michigamme iron district, Michigan	58	·03	·025	none
37.	Hornblende granite, Cecil Co., Maryland	58·5	·022	·018	none
38.	Latite, Tintic district, Utah	60	·007	·006	none
39.	Monzonite, Tintic district, Utah	60	·024	·02	tr.
40.	Diorite porphyry, La Plata Mts., Colorado	60·5	·02	·017	
41.	Trachyte-andesite tuff, Tuolumne Co., Calif.	62·5	·017	·014	
42.	Diorite, Douglas Isld., Alaska	63	·012*	·01*	none
43.	Rhyolite, San Miguel Co., Colorado	64·5	·004	·003	tr.
44.	Syenite, Mt. Ascutney, Vermont	65·5	tr.?	tr.?	
45.	Quartz-mica diorite, Tuolumne Co., Calif.	65·5	·013	·011	tr.
46.	Quartz monzonite, Calaveras Co., Calif.	67	·014	·012	none
47.	Rhyolite, Tintic district, Utah	69	·009	·008	tr.
48.	Quartz diorite, Amador Co., Calif.	69·5	·005	·004	tr.
49.	Trachyte, Highland Co., Virginia	69·5	tr.?	tr.?	
50.	Biotite granite, Amador Co., Calif.	70·5	tr.	tr.	tr.
51.	Rhyolite, Crater Lake, Oregon	71	·004	·003	ft. tr.
52.	Monzonite (altered), Tintic district, Utah	71	·021	·017	none
53.	Rhyolite quartz-porphyry, Tintic district, Utah	71·5	·016	·013	none
54.	Rock between rhyolite and dacite, Sutter Co., Calif.	71·5	tr.	tr.	
55.	Syenite porphyry, Mt. Ascutney, Vermont	73	none	none	
56.	Granite porphyry, Mt. Ascutney, Vermont	73·5	none	none	
57.	Granite, Union Co., Tennessee	76·5	none	none	

* Approximate.

TABLE II. *Component Minerals from certain of the above igneous rocks.*

No.	Name and source.	SiO_2 %	V_2O_5 %	$=V_2O_3$ %	Mo %
7[a].	Amphibole from 7	?	·075	·062	none
11[a].	Amphibole from 11	46	·044	·037	none
21[a].	Pyroxene from 21	51.5	·043	·036	
23[a].	Biotite from 23	36.5	·153	·127	none
29[a].	Amphibole from 29	50	·08	·066	
45[a].	Biotite from 45	?	·057	·048	none
46[a].	Biotite from 46	35·5	·08	·066	

TABLE III. *Miscellaneous.*

No.	Name and locality of occurrence.	SiO_2 %	V_2O_5 %	$=V_2O_3$ %	Mo %
58.	Epidotic schist, Mitchell Co., N. Carolina	48	·057	·047	
59.	Quartz schist, Madera Co., Calif.	79	tr.	tr.	
60.	Serpentine, Connecticut Valley, Massachusetts	38·5	none	none	
61.	Sea green roofing slate, West Pawlet, Vermont	68	·017	·014	
62.	Two red roofing slates (equal parts), Washington Co., New York	67 56	·008	·007	
63.	253 sandstones	78·5	·003	·003	
64.	498 building limestones	14	·004	·004	

Of the igneous rocks specimens were so selected as to represent not only many widely separated localities, but also numerous varieties from the least siliceous up to those high in silica, in order to ascertain whether a preconceived opinion that the vanadium accompanied chiefly the less siliceous rocks was well founded or not. The choice was, however, confined largely to those rocks analyzed in this laboratory within the past three or four years of which a supply of powder remained after the original analyses had been completed, and hence the list is perhaps not fully representative. Nevertheless it permits of drawing certain conclusions, the chief of which is that the vanadium predominates in the less siliceous igneous rocks and is absent or nearly so in those high in silica. The inference, based on the existence of the mineral roscoelite, classed as a vanadium mica, at once suggests itself, that the ultimate source of the vanadium may be one or more of the heavier silicates such as the biotites, pyroxenes, and amphiboles, and a few tests on all the available mineral separation products lend strong support to this view. For instance, the amphibole gabbros 7 and 11 show ·038 per cent and ·02 per cent V_2O_3, while the amphiboles 7[a] and 11[a] separated from them give ·062 per cent and ·037 per cent; the pyroxenic gneiss 23 shows ·083 per cent against ·127 from its contained biotite 23[a]; the diorite 29 with ·031 per cent contains an amphibole 29[a] with ·066 per cent; from ·011 per cent in the quartz-mica diorite 45 and ·012 per cent in the quartz monzonite 46 the percentages rise to ·048 and ·066 in their separated biotites 45[a] and 46[a]. The pyroxene

21[a] shows, however, practically the same amount as its mother rock, the syenitic lamprophyre 21.

In most of these cases, notably the last one, the vanadium in the separated mineral is not sufficiently in excess of that in the rock from which it was taken to account for all of that found in the latter. Hence, if the determinations are correct it must also be a constituent of some other mineral than the one analyzed. In roscoelite the trivalent condition of vanadium corresponding to the oxide V_2O_3 is now recognized as probable, although Roscoe's analysis reports V_2O_5 and Genth's an oxide intermediate between V_2O_3 and V_2O_5. This assumption seems to be necessary if the mineral is to be regarded as a mica, and it is then doubtless the equivalent of trivalent iron or aluminum. It would then be natural to look for it in the aluminous or ferric silicates of igneous rocks, certain biotites, pyroxenes, and hornblendes, and its absence in such minerals as serpentine and chrysolite, as shown by analyses 3 and 60, appears natural enough.

Few and inconclusive as the above comparisons are, they seem to favor strongly this view as to the source of the vanadium and in a measure are confirmatory of the observation of Hayes (Proc. Am. Ac., x, 294, 1875), who rather indefinitely associates it with phosphorus and proto-salts of iron and manganese, which are usually more prominent components of basic than of acid rocks.

We are probably justified by the evidence in tabulating the vanadium as V_2O_3 in analyses of igneous and some metamorphic rocks which have undergone little or no oxidation, but with sandstones, clays, limestones, etc., which are of more or less decided secondary origin, this is probably not the case. The probabilities are there largely in favor of its acid character and the existence of various vanadates of calcium, iron, aluminum, etc., in which case it should appear in analytical tables as V_2O_5.*

It was not until the greater part of the above tests had been finished that any careful attempt was made to identify molybdenum as well as vanadium. From the evidence gathered during the later part of the work it would seem that molybdenum when it does occur is a much less important constituent quantitatively than vanadium, and that unlike the latter it accompanies the more acid rocks. Molybdenite is a well known accessory constituent of some granites, etc., but in the above instances its amount was extremely small and no hint was obtained as to its state of combination.

* In the regular course of analysis vanadium will be weighed with alumina, iron, titanium, etc., since it is precipitated by both ammonia and sodium acetate in presence of those and other metals, hence the alumina percentages in

Chemical method employed.

In conclusion it is proper to outline the method by which the foregoing tests were carried out and to indicate the precautions that must be observed in order to insure good results.

Quite a number of workers have busied themselves with the problem of vanadium estimation in ores and rocks, particularly magnetites and other iron ores, and the methods used have been often diverse in parts if not altogether. There is nothing absolutely novel in the following except that chromium and vanadium when together need not be separated, but are determined, the former colorimetrically, the latter volumetrically in the same solution as detailed elsewhere.*

Five grams of the rock are thoroughly fused over the blast with twenty of sodium carbonate and three of sodium nitrate. After extracting with water and reducing manganese with alcohol it is probably quite unnecessary, if the fusion has been thorough, to remelt the residue as above, though for magnetites and other ores containing larger amounts of vanadium than any of these rocks, this may be necessary, as Edo Claassen has shown.† The aqueous extract is next nearly neutralized by nitric acid, the amount to be used having been conveniently ascertained by a blank test with exactly twenty grams of sodium carbonate, etc., and the solution is evaporated to approxi-

nearly all rock analyses heretofore made are subject to correction for the vanadium the rock may have held. This correction is of course to be made in terms of V_2O_5 and not of V_2O_3.

All determinations of iron are likewise affected by its presence whether as V_2O_5 or V_2O_3. As V_2O_3 it will make the FeO appear too high in the proportion V_2O_3: 4FeO, or 150·8: 288, an error which becomes appreciable in some of the basic rocks and amounts to ·25 per cent in the biotite 23[a]. As V_2O_5 the FeO will not be affected, but in either condition the Fe_2O_3 will need correction and to a different extent, according as the titration of iron is made after reduction by hydrogen sulphide or by hydrogen. If the former is used, as should always be the case in presence of titanium, the vanadium is reduced by it to V_2O_4, which in its action on permanganate is equivalent to two molecules of FeO representing one of Fe_2O_3, or only one-half as great as the influence on the FeO titration of the same vanadium as V_2O_3. An example will make this clear.

Found 2·50 per cent apparent FeO in a rock
containing ·13 per cent V_2O_3
Deduct ·25 per cent FeO equivalent in its action on
$KMnO_4$ to ·13 V_2O_3
Leaving 2·25 per cent FeO corrected.
Found 5·00 per cent apparent total iron as Fe_2O_3 in the same rock.
Deduct ·14 per cent Fe_2O_3 corresponding to ·13 per cent V_2O_3
Leaving 4·86 per cent corrected total iron as Fe_2O_3
Deduct 2·50 per cent Fe_2O_3 equivalent to 2·25 per cent FeO
Leaving 2·36 per cent Fe_2O_3 in the rock.

Failure to correct for the vanadium in both cases would have made the figures for FeO and Fe_2O_3 respectively 2·50 and 2·22 instead of 2·25 and 2·36 as shown above.

* Jour. Am. Chem. Soc., xx, pp. 454 and 461, 1898.

† Am. Chem. Jour., viii, 437.

mate dryness. Care should be taken to avoid overrunning neutrality because of the reducing action of the nitrous acid set free from the nitrite, but when chromium is present it has been my experience that some of this will invariably be retained by the precipitated silica and alumina, though only in one case have I observed a retention of vanadium, it being then large. The use of ammonium nitrate instead of nitric acid for converting the sodium carbonate into nitrate did not seem to lessen the amount of chromium retained by the silica and alumina.

As a precautionary measure therefore, and always when chromium was to be estimated also, the silica and alumina precipitate was evaporated with hydrofluoric and sulphuric acids, the residue fused with a little sodium carbonate and the aqueous extract again nearly neutralized with nitric acid and boiled for a few moments, the filtrate being added to the main one.

Mercurous nitrate was now added to the alkaline solution in some quantity so as to obtain a precipitate of considerable bulk containing chromium, vanadium, molybdenum, tungsten, phosphorus, and arsenic, should all happen to be in the rock, and also an excess of mercurous carbonate to take up any acidity resulting from the decomposition of the mercurous nitrate. Precipitating in a slightly alkaline instead of a neutral solution renders the addition of precipitated mercuric oxide unnecessary for correcting this acidity. If the alkalinity, as shown by the formation of an unduly large precipitate, should have been too great, it may be reduced by careful addition of nitric acid until an added drop of mercurous nitrate no longer produces a cloud.

After heating and filtering, the precipitate is ignited in a platinum crucible after drying and removing from the paper to obviate any chance of loss of molybdenum and of injury to the crucible by reduction of phosphorus or arsenic. The residue is fused with a very little sodium carbonate, leached with water, and the solution if colored yellow filtered into a graduated flask of 25 or more cubic centimeters capacity. The chromium is then estimated accurately in a few minutes by comparing with a standard alkaline solution of potassium monochromate.* Then, or earlier in absence of chromium, sulphuric acid is added in slight excess and molybdenum and arsenic together with occasional traces of platinum are precipitated by hydrogen sulphide, preferably in a small pressure bottle.† If the color of the precipitate indicates absence of arsenic, the filter with its

*Jour. Am. Chem. Soc., xx, 454, 1898.

† From a sulphuric solution the separation of molybdenum by hydrogen sulphate is much more rapid and satisfactory than from a hydrochloric solution.

contents is carefully ignited in porcelain and the delicate sulphuric acid test for molybdenum is applied.

The filtrate, in bulk from 25 to 100^{cc}, is boiled in a current of carbon dioxide to expel hydrogen sulphide, and titrated at a temperature of 70–80° C. with a very dilute solution of permanganate representing about one milligram of V_2O_5 per cubic centimeter as calculated from the iron strength of the permanganate, one molecule of V_2O_5 being indicated for each one of Fe_2O_3. One or two checks are always to be made by reducing again in a current of sulphur dioxide gas, boiling this out in a current of carbon dioxide again, and repeating the titration.

As shown in a previous paper* the presence of even thirty times as much Cr_2O_3 as V_2O_5 does not prevent a satisfactory determination of the vanadium if the precautions therein given are observed, provided there is present not less than ½–1 mg. of V_2O_5 in absolute amount. In absence of chromium less than half a milligram can be readily estimated. The phosphoric acid almost invariably present does not affect the result.

In case the volume of permanganate used is so small as to make doubtful the presence of vanadium, it is necessary to apply a qualitative test which is best made as follows: The solution is evaporated and heated to expel excess of sulphuric acid, the residue is taken up with two or three cubic centimeters of water and a drop or two of dilute nitric acid, and a couple of drops of hydrogen peroxide are added. A characteristic brownish tint indicates vanadium. Unless the greater part of the free sulphuric acid has been removed the appearance of this color is sometimes not immediate and pronounced, hence the above precaution.

The above is a surer test to apply than the following: Reduce the bulk to about ten cubic centimeters, add ammonia in excess and introduce hydrogen sulphide to saturation. The beautiful cherry-red color of vanadium in ammonium sulphide solution is much more intense than that caused by hydrogen peroxide in acid solution, but the action of ammonia is to precipitate part or all of the vanadium with the chromium or aluminum that may be present or with the manganese used in titrating, and ammonium sulphide is unable to extract the vanadium wholly from these combinations. Usually, however, the solution will show some coloration, and addition of an acid precipitates brown vanadium sulphide, which can be collected, ignited and further tested if desired.

*Jour. Am. Chem. Soc., xx, 464, 1898.

Summary of Results.

Vanadium occurs in quite appreciable amounts in the more basic igneous and metamorphic rocks, up to ·08 per cent or more of V_2O_3, but seems to be absent or nearly so from the highly siliceous ones. The limited evidence thus far obtained points to the heavy ferric-aluminous silicates as its source—the biotites, pyroxenes, amphiboles. As opportunities offer further evidence will be accumulated and it is hoped that other chemists will lend their aid.

Limestones and sandstones appear to contain very small amounts of vanadium, as shown by analyses of a composite sample of each aggregating over 700 different occurrences.

From the few tests for molybdenum it appears as if this element were confined to the more siliceous rocks. It is present in no observed case in amount sufficient for quantitative measurement when operating on five grams of material.

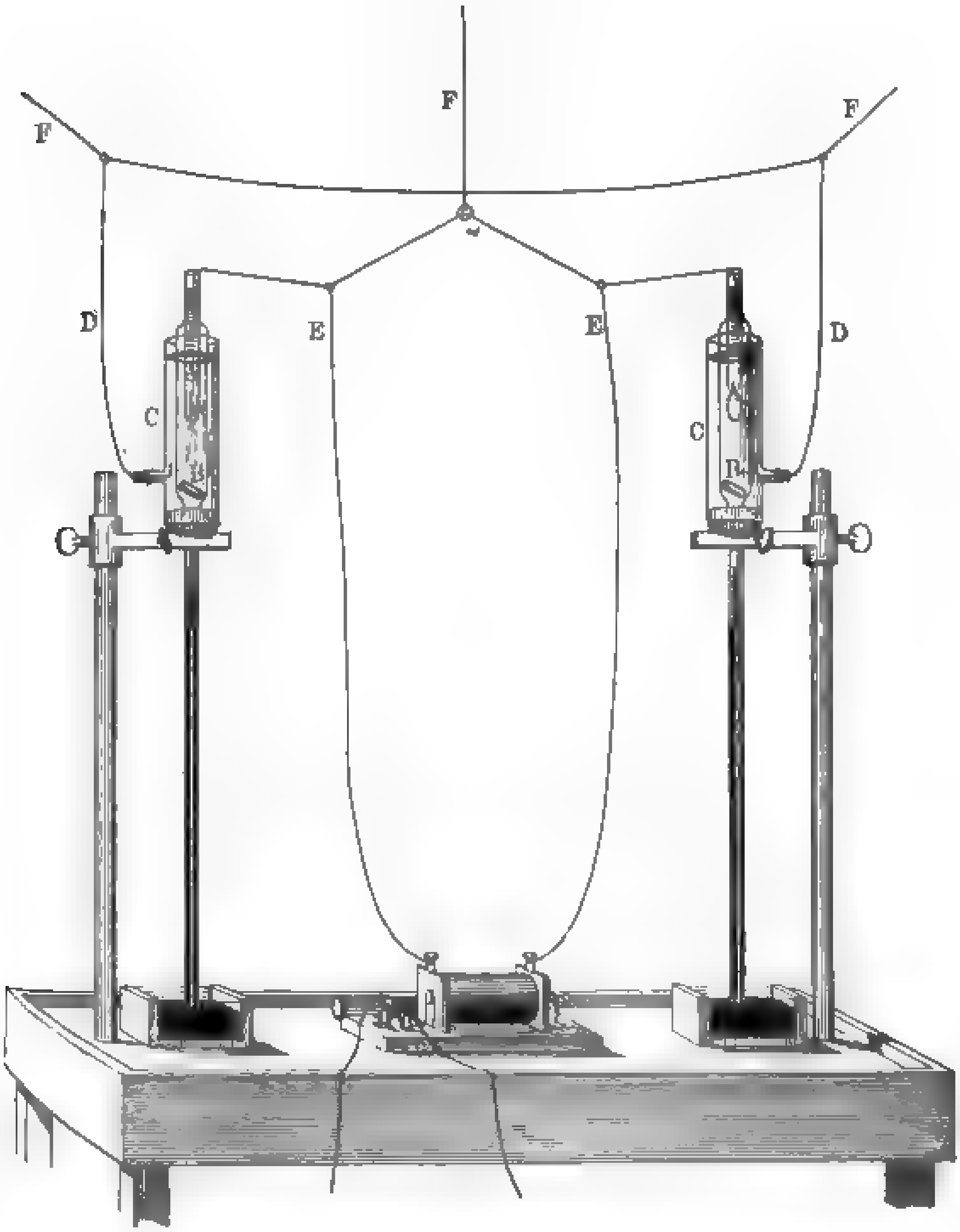
Laboratory of the U. S. Geological Survey,
Washington, D. C., May 1898.

Note. Since the above was written a few tests have been made on minerals of which powdered samples were at hand. A phlogopite from Burgess, Canada, gave ·007 per cent V_2O_3. Mica from Laurel Hill, Georgia, gave ·026 per cent V_2O_3. Protovermiculite from Magnet Cove, Ark., gave ·04 per cent V_2O_3. Hallite from Chester Co., Pa., gave ·01 per cent V_2O_3. Jeffersonite from Franklin, N. J., gave none, and a non-ferruginous amphibole from St. Lawrence County, N. Y., gave a faint trace.

ART. XXII. — *On Electrosynthesis;* by W. G. MIXTER. (Second paper.)

[Contributions from the Sheffield Laboratory of Yale University.]

THE apparatus described in the first paper* was used in the work. For convenience the figure of it is reproduced. The gases in the two eudiometers at the commencement of an experiment were, unless otherwise stated, at nearly the same pressure, which was less than 200^{mm} of mercury. The volumes



of the gases are either given in cubic centimeters reduced to 0° C. and 760^{mm} pressure, or in numbers expressing the proportional number of volumes of each gas. Solid potassium

* This Journal, vol iv, p. 51.

hydroxide was used to absorb water in the eudiometer containing hydrogen and oxygen, and a saturated solution was used in the other eudiometer unless a different reagent is mentioned. The same empirical measure was employed as before, which is the amount of hydrogen and oxygen combining in one eudiometer while the gases in the other eudiometer also combined, the same current passing through both eudiometers. The numerous details common to all of the experiments are omitted, while any modification is fully described. Many experiments were made while the work was in progress with electrolytic hydrogen and oxygen in both eudiometers in order to find if the apparatus was working well, to test the method more fully and to study the conditions affecting the rate of change produced by a given current through the apparatus.

The view expressed in the first paper, that heat resulting from the combination effected by the feeble glow discharge does not cause further combination, is supported by the following results. The jacket tube C shown in the figure was replaced by a wire wound twice around B, opposite the lower end of A and connected with the wire D. With this arrangement the discharge is concentrated but without sparks, and the glow is more intense than in the jacketed tube. The eudiometers in the following tests contained hydrogen and oxygen:

	Diffused discharge.	Concentrated discharge.
Exp. 1	$1{\cdot}88^{cc}$ combined.	$1{\cdot}89^{cc}$ combined.
" 2	2·55 "	2·67 "

The heat of combustion was the same in the two tubes as equal quantities of gases united, but it was distributed through several times the volume of gas in one case than in the other. If the heat resulting from the action in the feeble glow discharge causes chemical union, we should expect in the other case where the temperature is obviously higher, since the same amount of heat is generated in a smaller volume, that the resultant combination would be greater. As it was not found to be so, we conclude that the heat of combination does not cause further union of the gases. If, however, the discharge is sufficiently powerful we should expect a different result. This was found to be so, for with a stronger current through the apparatus the concentrated discharge caused three times as much combination as the diffused discharge.

When a solution, instead of solid potassium hydroxide, is used in a eudiometer through which a current is passing, a feeble spark is perceptible if the finger is held near the mercury in the trough, but none is felt when a eudiometer does not contain a solution. For the following experiments the sides of one eudiometer were coated with a saturated solution of potassium hydroxide from the top of the mercury column nearly to the inner tube A:

	With solution of KOH.	With solid KOH.
Exp. 1	$2{\cdot}79^{cc}$ combined.	$2{\cdot}63^{cc}$ combined.
" 2	6·30 "	6·64 "

These results show that the presence of a solution does not influence the rate of change produced by the current through hydrogen and oxygen.

For a time the coil used gave a feeble and intermittent glow in one eudiometer and a fairly steady one in the other. Upon changing the direction of the primary current these effects were frequently reversed. The intermittent discharge in a eudiometer caused less oxygen and hydrogen to unite than the steady discharge. Moreover, the rate of combination was much slower than had been obtained in previous experiments with the same coil actuated by the same current. Two other smaller coils which have been in the chemical laboratory many years gave the same abnormal results. An examination of the first coil mentioned showed that some of the connections were corroded. When put in order it gave good results again. Later a new and larger coil yielding a 4-inch spark was used with satisfactory results, the break being adjusted to give a spark of 1 to 2 centimeters.

A number of experiments were tried with hydrogen and oxygen at widely different pressures in the two eudiometers to find if there is any simple relation between the rate of combination and pressure. The results, however, only confirm the statement in the first paper that the higher the pressure the more rapid the combination.

In the previous paper allusion was made to the fact, when the eudiometers were near together and the coil was connected with only one of them, that a glow sometimes appeared in the other. To find if combination occurs under such conditions one eudiometer containing oxygen and hydrogen under a pressure of $10{\cdot}9^{mm}$ was placed 6 centimeters from the other eudiometer containing air at a pressure of 3^{mm}. The two were insulated by wood and glass. The mercury in the trough of the one containing air and the water in the tube A were connected with the coil actuated by a current of 3 amperes. The discharge was brilliant and striated, and caused a distinct glow in the oxygen and hydrogen visible in a dark room when the light of the other tube was shut off by a screen of black paper. The glow was much brighter on the side towards the screened tube. After two hours the pressure had fallen $2{\cdot}3^{mm}$, and the gas, which was originally $1{\cdot}64^{cc}$, was reduced to $1{\cdot}32^{cc}$, the water formed being taken up by solid potassium hydroxide. When the eudiometers were 13 centimeters apart the combination was perceptible but much slower. It is evident that a very feeble electric action causes the oxidation of hydrogen, and

this suggests that the hydrogen continually passing into the atmosphere but not accumulating may be at least to a considerable extent oxidized by the electricity of the aurora. As stated in the first paper, vapor of water is decomposed by the glow discharge. To find the amount of decomposition and to find how completely hydrogen and oxygen combine in the presence of water, vapor of water in one eudiometer and moist hydrogen and oxygen in the other were submitted to the glow discharge produced by a current of one ampere in the primary of the coil. In four hours the pressure was the same in both tubes and $0{\cdot}8^{mm}$ greater than the pressure of water vapor at the temperature, which was 17·8°. With a current of 1·8 amperes the pressure increased $0{\cdot}9^{mm}$. The results show that the electrolytic hydrogen and oxygen used almost completely combined to form water, also that with a given current through the apparatus as described a state of equilibrium in the gases results.

Ammonia and Oxygen.

A mixture of $23{\cdot}6^{cc}$ of oxygen and $28{\cdot}8^{cc}$ of ammonia contracted $23{\cdot}9^{cc}$, while one of hydrogen and oxygen contracted $18{\cdot}6^{cc}$. The nitrogen gas remaining after the electric discharge ceased to cause further contraction in the gaseous mixture was only $\frac{5}{6}$ of the nitrogen supplied by the ammonia, the remainder having entered into a non-gaseous compound. This was ammonium nitrite, which formed a white coating on the sides of the eudiometer, and which reacted for nitrous acid with the usual tests. Nitrate was probably also formed. The relative proportions of the two reactions may be represented by the equations

$$10NH_3 + 7\tfrac{1}{2}O_2 = 5N_2 + 15H_2O$$
$$2NH_3 + 1\tfrac{1}{2}O_2 = NH_4NO_2 + H_2O$$
$$24 \text{ vols.} \quad 18 \text{ vols.} \quad 10 \text{ vols.}$$

In the experiment 100 volumes of oxygen and hydrogen to 128 volumes of ammonia and oxygen disappeared; as 10 volumes of nitrogen remain for every 42 volumes of ammonia and oxygen reacting, we have $128 \times \frac{42}{32} = 168$ for the total number of volumes of the two gases combined. Of these 88 are ammonia oxidized, 72 oxygen, and 8 are ammonia combined in the nitrite.

In the second experiment there was more of a deposit of ammonium nitrite than in the first and the residual nitrogen was $\frac{3}{4}$ of that supplied by the ammonia taken, and for 100 volumes of oxygen and hydrogen 141 volumes of the mixture of ammonia and oxygen disappeared; or allowing for the nitrogen gas 179, consisting of 89 volumes of ammonia oxidized, 13 combined in nitrite and 77 of oxygen.

Amines and Oxygen.

A mixture of 20^{cc} of oxygen and 10^{cc} of methylamine gas contracted $12{\cdot}4^{cc}$, while hydrogen and oxygen contracted $6{\cdot}4^{cc}$, a ratio of 194 to 100. Assuming the reaction to be

$$\underset{4 \text{ vols.}}{2NH_2CH_3} + \underset{9 \text{ vols.}}{4\tfrac{1}{2}O_2} = \underset{2 \text{ vols.}}{N_2} + 2CO_2 + 5H_2O$$

and allowing for the nitrogen, we have $194 \times \frac{13}{11} = 229$ volumes, of which 70 are methylamine and 159 are oxygen. The solution of potassium hydroxide after the experiment reacted for nitrous acid, and assuming

$$\underset{4 \text{ vols.}}{2NH_2CH_3} + \underset{13 \text{ vols.}}{6\tfrac{1}{2}O_2} = 2NO_2 + 2CO_2 + 5H_2O$$

the 194 volumes consist of 46 of methylamine and 148 of oxygen. The two reactions occur simultaneously and we may consider that methylamine is oxidized somewhat slower than hydrogen.

The ratio observed between a mixture of hydrogen and oxygen and one of dimethylamine and oxygen was 100 to 300 volumes with formation of nitrous acid. Calculated as for methylamine we find 70 volumes of dimethylamine oxidized on the assumption that all of the nitrogen is set free, and 57 volumes, assuming the nitrogen to form NO_2.

Trimethylamine and oxygen gave a very different result from the two preceding, as no nitrous acid was detected. It may have been formed and decomposed by the amine. For 100 volumes of hydrogen and oxygen 265 of trimethylamine and oxygen combined, consisting of 42 of trimethylamine and 223 of oxygen.

A mixture of aniline vapor and oxygen at 30° C. and 100^{mm} pressure contracted very slowly when subjected to the glow discharge and a brown condensation product was deposited on the sides of the tube. No nitrous acid was detected in the products.

Cyanogen and Oxygen.

A mixture of one volume of dry cyanogen and two volumes of oxygen was subjected to the glow discharge. For a time it increased a little in volume, and afterwards slowly contracted to about the original bulk of the mixed gases. A solution of barium hydroxide was added to absorb carbon dioxide and any cyanogen left. The gases remaining after this treatment contracted much and when again subjected to the discharge more barium carbonate formed. Two tests were made, using potassium hydroxide solution as an absorbent, with similar but unsatisfactory results. Scarcely more than a trace of nitrous acid was detected. The changes caused by the glow discharge are too complicated to admit of an accurate comparison with the

rate of change in hydrogen and oxygen, but the observations made indicate that cyanogen is oxidized faster than hydrogen. The products are carbon monoxide and dioxide, free nitrogen and a small proportion of condensation products and oxides of nitrogen. It was found that pure cyanogen gas condenses very slowly with formation of a brown product when subjected to the glow discharge.

Nitrous Oxide. 1st Experiment.

	Nitrous oxide.	Change.	Hydrogen and oxygen.	Change.
	18·46^{cc}		30·^{cc}	
1st hour....	18·77	+0·31^{cc}	25·5^{cc}	−4·5^{cc}
2d "	19·56	+0·79	21·5	—4·
3d "	20·17	+0·61	17·6	−3·9

The saturated solution of potassium hydroxide on the sides of the eudiometer containing the nitrous oxide became dry with the formation of nitrite and probably nitrate.

2d Experiment.—A solution of pyrogallic acid in potassium hydroxide was used to absorb the oxygen set free from the nitrous oxide. 12·85^{cc} of the latter gas were changed by the discharge to 11·9^{cc}, while 5·6^{cc} of hydrogen and oxygen combined.

3d Experiment.—Nitrous oxide increased 1·7^{cc} in half an hour while hydrogen and oxygen contracted 2·8^{cc}. During the next half hour the volume of the gas in tube originally containing nitrous oxide remained unchanged, while 3·3^{cc} of hydrogen and oxygen united.

The results show that the glow discharge causes complicated changes in nitrous oxide. The increase in volume of 1·7^{cc} corresponds to 3·4^{cc} according to the equation $N_2O = N_2 + O$; that is, 100 volumes of hydrogen and oxygen combined and 121 volumes of nitrous oxide decomposed. The other experiments show a much lower result for the oxide, but the volume change was not observed until the action of the current had continued an hour or longer. The contraction in the second experiment shows that some of the nitrous oxide is changed according to one or the other of the equations

$$3N_2O = N_2O_3 + 2N_2$$
$$4N_2O = 2NO_2 + 3N_2$$

Nitrous Oxide and Hydrogen.

Two experiments were made with a mixture containing a little more hydrogen than nitrous oxide. For 100 volumes of hydrogen and oxygen combined the mixture of nitrous oxide and hydrogen contracted respectively 54 and 58, or an average of 56 volumes. The potassium hydroxide in the eudiometer

reacted for nitrite. As it has been shown that nitrous oxide undergoes little change in volume when subjected to the glow discharge, we may consider the change in volume when hydrogen is present to be

$$N_2O + H_2 = N_2 + H_2O$$

and that 56 volumes of hydrogen were oxidized by 56 of nitrous oxide. As the latter is endothermic it is remarkable that it does not oxidize hydrogen as rapidly as free oxygen.

Nitric Oxide.

When nitric oxide in a eudiometer containing a solution of potassium hydroxide is subjected to the glow discharge the volume of the gas contracts rapidly at first, then slowly until the discharge causes no further change and nitrogen is left. In the experiments there was one volume of the residual gas for 5, 4·96, 5·4, 5·3 and 4·88, a mean of 5·11 volumes of nitric oxide taken. The change is according to the equation

$$\underset{10\ \text{vols.}}{5NO} = NO_2 + N_2O_3 + \underset{2\ \text{vols.}}{N_2}$$

In three experiments for every 100 volumes of hydrogen and oxygen combined 153, 160 and 167, an average of 160 volumes, disappeared; allowing for the nitrogen set free, we have $160 \times \frac{5}{4} = 200$ volumes of nitric oxide involved in the change. Assuming that $\frac{2}{5}$ of the nitric oxide is decomposed into nitrogen and oxygen, the latter combining with nitric oxide to form higher oxides, we have $\frac{2}{5}$ of $200 = 80$ volumes of nitric oxide decomposed to 100 of hydrogen and oxygen combined. It is highly probable that the glow discharge changes nitric oxide directly into higher oxides. If so the relative change caused by the electricity is greater than that indicated by the calculation.

Nitric Oxide and Hydrogen.

A mixture of equal volumes of nitric oxide and hydrogen contracted in comparison with 100 volumes of hydrogen and oxygen in two experiments respectively, 91 and 92 volumes. This is about $\frac{9}{16}$ of the contraction observed when nitric oxide alone was used, and the results indicate that the hydrogen present retarded the action by diluting the gas. The potassium hydroxide in the eudiometer reacted for nitrite, showing that hydrogen did not take up all of the oxygen of the nitric oxide dissociated. This was to be expected, as nitric oxide combines with free oxygen more readily than hydrogen at common temperatures. The experiments do not show that hydrogen was oxidized. Assuming, however, that all of the contraction in volume was due to the reaction $NO + H_2 = N + H_2O$, we find that nitric oxide does not oxidize hydrogen as rapidly as does oxygen.

Nitric Oxide and Carbonic Oxide.

Experiment 1.—Equal volumes of mixed nitric oxide and carbonic oxide contracted 6^{cc} and hydrogen and oxygen $3{\cdot}8^{cc}$.

Experiment 2.—A mixture of $6{\cdot}5^{cc}$ of nitric oxide and 8^{cc} of carbonic oxide left $8{\cdot}6^{cc}$ of gas when the electric discharge caused no further contraction.

Experiment 3.—A solution of barium hydroxide used as an absorbent became but slightly turbid when the glow discharge acted on a mixture of nitric and carbonic oxide.

These results show that the contraction of the mixed oxides is about the same as that of nitric oxide, and that the glow discharge acts chiefly on the nitric oxide in the mixture, also that some carbonic oxide is oxidized.

Molecular Changes.

The following table is based on the change in volumes observed, and one volume of hydrogen and oxygen is considered to contain 100 molecules.

Gases used.	Molecules reacting.	Molecules oxidized.		Molecules of oxygen consumed.
Hydrogen and oxygen	100	H_2	67	33
Ammonia "	168	NH_3	88	72
" "	179	"	89	77
Methylamine "		NH_2CH_3	46 to 70	
Dimethylamine "		$NH(CH_3)_2$	57 to 70	
Trimethylamine "	265	$N(CH_3)_3$	42	213
Hydrogen and nitrous oxide,	112	H_2	56	
" nitric "	Little if any hydrogen oxidized.			
Carbonic oxide and nitric oxide.	Some carbonic oxide oxidized.			

Cyanogen is probably more rapidly oxidized than hydrogen, but further work is needed to settle this point. It is probable that more molecules of nitrous oxide are changed than of hydrogen and oxygen combined. In the case of nitric oxide, if we suppose that the glow discharge simply separates the compound into its elements, we find that 80 molecules are decomposed to 100 molecules of hydrogen and oxygen combined. This supposition is equivalent to the assumption that higher oxides are not formed by the direct combination of two or three molecules of nitric oxide with separation of nitrogen. It does not appear that the nature of the reaction can be determined by experiment.

The glow discharge used is too feeble to oxidize nitrogen, but when it causes the oxidation of nitrogenous compounds the nitrogen is more or less oxidized. In conclusion it may be stated that a mixture of carbon disulphide and oxygen at a pressure of 138^{mm} was exploded by the feeble glow discharge; also that the synthesis of formic acid from carbonic oxide and water vapor and from hydrogen and carbon dioxide was found to be much slower than the synthesis of water.

Art. XXIII.—*Notes on species of Ichthyodectes, including the new species I. cruentus, and on the related and herein established genus Gillicus;* by O. P. Hay, Ph.D.

Ichthyodectes hamatus Cope.

Cope, 1872, Proc. Amer. Philos. Soc., vol. xii, p. 340; 1875, Cretaceous Vertebrates, p. 209, pl. xlvi, figs. 5, 5*a*.

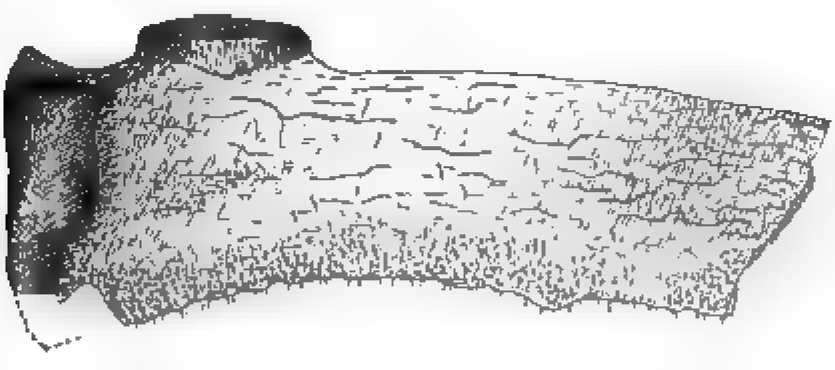
Of this species I possess two nearly complete dentaries. The tooth-line has a length of 100^{mm}. One dentary has 27 teeth; the others 28. Prof. Cope states that the mandibular in his possession displayed 25 teeth, but it is quite probable that there is considerable individual variation in the number. The form of the jaw and the presence of the upturned symphysial hook indicates that my specimens belong to Cope's *I. hamatus*. The teeth are closely arranged and they show a peculiarity of form and setting that has not been noticed by Prof. Cope. This peculiarity is found in the fact that the teeth are elliptical in section, with the long axis of the section placed obliquely to the axis of the tooth-line, its outer end being thrown forward. The longer axis will average close to 5^{mm} in length, the shorter about 3^{mm}. The alveolar border is somewhat scooped out on the inner side just behind the hook, and just here the teeth are smaller than elsewhere. On the hook itself there are two teeth. The enamel is smooth.

Ichthyodectes cruentus sp. nov.

Figs. 1 and 3.

This supposed new species is founded primarily on a somewhat imperfect left maxilla which came from Butte Creek

1.

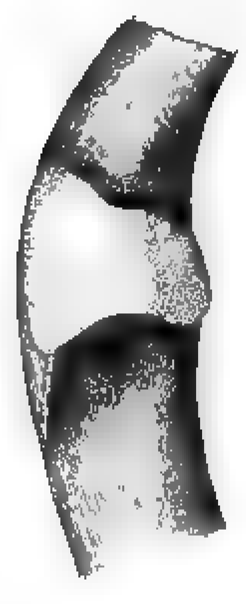


Canyon region in western Kansas. I have also a nearly perfect dentary and portions of one or two others which apparently belong to the same species. Of the maxilla, the anterior extremity, including the anterior condyle, is wanting, and also the distal extremity (fig. 1 × $\frac{3}{8}$).

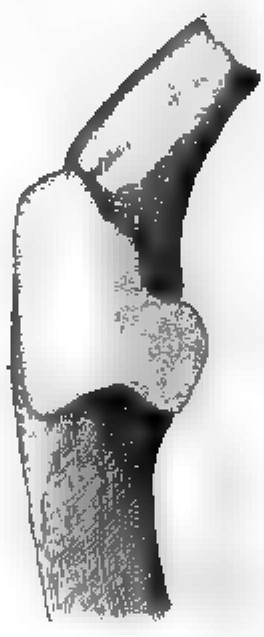
This species appears to be nearest to Prof. Cope's *I. anaides.* It differs, however, in having larger teeth, as well as in some other respects. In my possession is the maxilla of a specimen of the last named species which has the depth from the upper surface of the palatine condyle to the tooth-line equal to that of *I. cruentus.* In this maxilla of *I. anaides* I find about 10 teeth to the inch; in *I. cruentus* there are only 7 teeth to the inch. The teeth being larger, we find that the alveolar border of the maxillary is thicker than in *I. anaides.* Indeed, the whole bone is of heavier construction. In *I. anaides* the mesial surface is nearly flat, or even has a wide shallow groove some distance below its upper border. In *I. cruentus* the mesial surface is decidedly convex. In *I. anaides* the upper border is flattened at right angles with the outer surface of the bone; while in *I. cruentus* it is gradually rounded off, from a sharp outer edge, into the mesial surface.

The palatine condyles of the maxillæ of the two species are quite different. Figure 2 represents that of *I. anaides,* of natural size. Figure 3 shows that of *I. cruentus,* also of natural size. Further descriptions are not required.

2.



3.



From *I. ctenodon* (Cope, Cret. Vert., p. 208, pl. xlvi, figs. 1–4) this species differs in having a high, not a low, palatine condyle. The maxillary of *I. ctenodon* is said to be a rather thin and narrow bone.

I. hamatus has a maxillary whose dental border is very concave. According to Cope's figure, there must have been 10 or 12 teeth to the inch (Cope, Cret. Vert., p. 209, pl. xlvi, fig. 5).

I. prognathus also must have had smaller teeth, judging from Cope's figure of the premaxillary (Cope, Cret. Vert., p.

210, pl. xlvi, fig. 6). Cope also states that the palatine condyle of *I. prognathus* reached "a point above the middle of the alveolar margin of the premaxillary." This is certainly not true of *I. cruentus*.

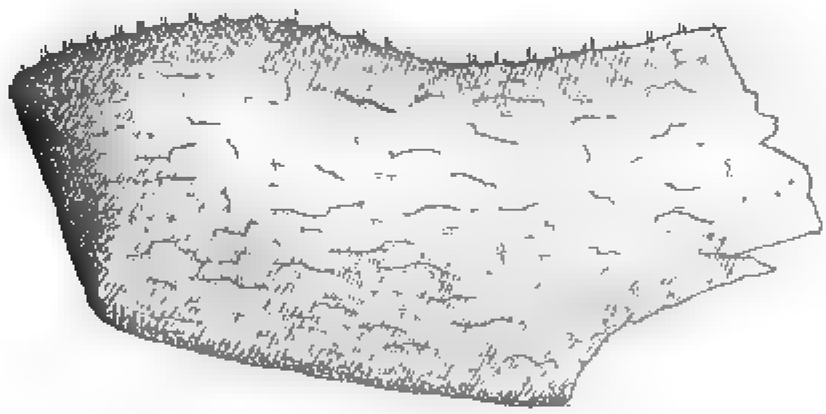
In *I. multidentatus* (Cope, Cret. Vert., p. 212) the teeth are small, about 12 to the inch, and are marked by ridges and grooves.

In *I. goodeanus* (Cope, Proc. Amer. Philos. Soc., xvii, p. 176) the maxillary tooth line is directed upward and inward in front and then becomes convex. The palatine condyle is said to be not protuberant. *I. acanthicus* (Cope, loc. cit., p. 177) is a small species which has the dentary teeth attenuated and curved inward at the apex.

Newton has given descriptions of two English species of this genus, *I. minor* (Egerton) and *I. elegans* Newt. (Quart. Jour. Geol. Soc., xxxiii, p. 520.) *I. minor* has a very straight mandibular tooth-line; *I. elegans* has extremely long, forwardly projecting mandibular teeth.

Length of portion of maxilla of *I. cruentus* here described, 100^{mm}; depth at middle of palatine condyle, 34^{mm}; depth at point 34^{mm} behind the palatine condyle, 28^{mm}.

4 × ½.



Where the bone is fractured near its distal end there are shown in its interior large medullary cavities, now occupied by calcite.

The dentary bone which I regard as belonging to this species is shown by figure 4. Nearly the whole of the tooth-line is present, perhaps not more than 3 or 4 teeth being missing. This indicates that there were 30 teeth. The alveolar border is sinuous, being strongly concave behind the middle and rising further behind. In front of the concavity the border is convex, and then descends to the symphysis. The convexity appears to correspond to the concavity of the alveolar border of the maxilla; while the symphysial descent corresponds to the downward slope of the anterior end of the maxilla, which

slope was probably continued forward by the premaxillary. In a fragment of the dentary which I regard as belonging to this species there is preserved one tooth complete. It is straight, 7^{mm} high and the enamel is smooth.

Ichthyodectes arcuatus Cope and *I. polymicrodus* Crook.

Portheus arcuatus Cope, 1875, Cret. Vert., pp. 193, 204, 274, pl. xlvii, figs. 7–9 (figures doubtful).
Ichthyodectes arcuatus Cope, Proc. Amer. Philos. Soc., vol. xvii, p. 177; 1892, Amer. Nat.. vol. xxvi, p. 942.
Ichthyodectes polymicrodus Crook, A. J., 1892, Palæontographica, vol. xxxix, p. 112, pl. xvi.

In *Palæontographica*, as above cited, Dr. Crook has described as new a species of fossil fish from the Cretaceous deposits of western Kansas and has bestowed on it the name *Ichthyodectes polymicrodus*. This species he compares with Prof. Cope's *Ichthyodectes multidentatus* and concludes that the two are distinct species. In this conclusion he is doubtless correct, because of the evident difference in the size and number of teeth in the two forms. I can, however, with difficulty accept Dr. Crook's statement that the maxilla of his species possessed 24 teeth to the centimeter. This might possibly be true of the distal end of the maxilla, where they become very small, but not for the anterior end, even according to Dr. Crook's figure. In Cope's species, *I. multidentatus*, there were only 5 teeth to the centimeter.

In a review of Dr. Crook's paper (Amer. Naturalist, vol. xxvi, p. 941) Prof. Cope claims that Dr. Crook's species is the same as that originally described by Cope as *Portheus arcuatus*, and which is retained by Crook in *Portheus*, but transferred by Cope to *Ichthyodectes*. It is hard to understand why the species was originally placed in *Portheus*, since its dentition is very different from that of this genus. There appears to have been some confusion in Prof. Cope's mind regarding this species. It was founded on somewhat imperfect maxillary and palatine bones, and the original description given of it pertained to these bones. (Cret. Vert., p. 204.) On page 274 of the *Cretaceous Vertebrates*, under this species, Cope refers to plate xlvii, figs. 7–9. When we turn to this plate we find figures of what appears to be an *Ichthyodectes*. On the plate they are said to belong to *? Portheus arcuatus;* while in the explanation of the plate they are referred to *Portheus? arcuatus*, We are therefore unable to say whether Prof. Cope was in doubt as to the species or the genus. On page 220 B, line 16, two of the same figures are mentioned as those of "the cranium of an unknown species" of Saurodontidæ. In his review of Dr. Crook's paper, Prof. Cope states that had it not been for certain conditions the figures of his species would have

been published, a statement which certainly implies that figures of it had not been published.

I have in my possession portions of several individuals that evidently belong to, or are very closely related to, Crook's species, and I am convinced that if Prof. Cope's figures, designated as belonging to his *Portheus arcuatus*, really pertain to it the latter and *Ichthyodectes polymicrodus* are very different. The parasphenoids of the two forms are different, as well as other bones, as Dr. Crook has observed. The latter held that Prof. Cope's figures belonged to *Ichthyodectes anaides*.

Having settled this, we return to the description of the type specimens of *Portheus arcuatus*, the maxillary and palatine. I quote Prof. Cope's language: "Apart from its small size, this species may be known by the compressed and concave alveolar border behind and below the posterior maxillary condyle and the very small size of the teeth which protrude from its subacute edge." It seems to me that this language and that which follows it (Cret. Vert., p. 204), as well as that employed in Proc. Amer. Philos. Soc., xvii, 177, agrees so well with the figure and description of Dr. Crook's species that no facts presented by him enable us to distinguish it from Prof. Cope's species. Nevertheless, it seems hardly safe as yet to unite the two. We ought to have more accurate descriptions of both. In looking over my specimens it seems to me that I can observe characters that indicate two species. In one maxilla I find that the posterior, or palatine, condyle is comparatively short and has in its hinder border a distinct notch; in other maxillæ the condyle is longer and apparently without the posterior notch. The distance between the condyles appears to be much greater in some cases than in others. There also appear to be some differences in the forms of the maxillæ.

While these forms can by no means belong to Cope's *Portheus* (*Xiphactinus* of Leidy), they can hardly belong to the genus *Ichthyodectes*. In the latter genus the maxilla is long, nearly equal to the distance from the tip of the vomer to the occipital condyle. The gape of the mouth must therefore have been large. In Dr. Crook's species and related forms, the maxilla is short, between one-half and two-thirds the distance referred to above; hence the gape of the mouth must have been rather small. The maxillæ of typical species of *Ichthyodectes* are nearly straight along the tooth-line, or sinuous, or, in *I. hamatus*, strongly concave. In *I. polymicrodus* the tooth-line is strongly convex, except just behind the palatine condyle. The teeth of *I. polymicrodus* are numerous and feeble: in the other species strong and in smaller number. Hence, for Prof. Cope's *I. arcuatus* and Dr. Crook's *I. polymicrodus* I propose the new generic name

GILLICUS.

Characters. A Saurocephalid with maxilla falciform, relatively short; teeth with roots, numerous, small. Gape of mouth smaller than in *Ichthyodectes.* Mandible deep. Base of skull with strong upward flexure. Scales large.

The genus is named in honor of Dr. Theodore Gill of the National Museum, who has also made additions to our knowledge of the fossil fishes. The generic name is formed in analogy with the word Aristophanicus.

As type of this genus I take Crook's *I. polymicrodus*, since it has been figured. Should this be shown to be the same as Cope's *I. arcuatus*, the latter name of course takes precedence.

Crook has interpreted the bones of the posterior upper region of the skull of his *I. polymicrodus* as he has those of *Portheus* (*Xiphactinus*); but, as in the case of the latter I am compelled to differ with him. However, many of the sutures are very difficult to demonstrate. According to Crook, the supraoccipital is greatly expanded in front, while the parietals lie laterad of the epiotics. It seems to me that the supposed expanded portion of the supraoccipital is really the area belonging to the parietals. There is a very distinct fold running along the hinder border of the expansion, and this, continuing up to the midline, has the appearance of a suture. In the crushed specimen before me, there is, along the middle line of the expansion, a break in the bone, but whether due to a fracture or to the parting of the bones along a suture, I cannot determine. Possibly the parietals were coössified along the midline. As to Crook's parietal, I cannot convince myself that there is any suture cutting off the area assigned to it from that assigned to the pterotic. I regard as pterotic the whole area extending from the posterior external angle of the skull to the lateral expansion considered by Crook as supraoccipital. See Crook's fig. 5, pl. xvi, Sq and Pa.

Crook's determinations of the proötic and the opisthotic are undoubtedly erroneous. His proötic is nothing but the lateral process of the parasphenoid which rises, on each side, to bound the eye-muscle canal. His opisthotic is the true proötic. It rises to the post-frontal, and assists in forming the articular surface for the hyomandibular, just as it does in *Xiphactinus* and our modern tarpon. The opisthotic is to be looked for further behind, and it seems to me that it occupies the whole or part of the area of Crook's figure 6, pl. xvi, which is designated by *Ocl.* There is in the side of the skull a deep excavation such as existed in the skull of *Xiphactinus* and exists in the skull of *Tarpon;* and the specimen in my hands and Dr. Crook's figure 6 give me the impression that, as in *Tarpon*

and probably *Xiphactinus*, the opisthotic sends forward a process below this excavation.

A remarkable feature of the head of this genus is found in the upward flexure of the forward part of the skull. At the anterior end of the basioccipital there is formed an angle of about 55° between the basal and the anterior parts of the skull. This reminds us of the figure of a young tarpon presented by Dr. Shufeldt in his work on Amia (Ann. Rep. Comm. Fish and Fisheries for 1883 (1885), pl. xiv). As regards *Tarpon* it is to be noted that in the adult fish this angle is greatly reduced, not exceeding perhaps 10°.

It seems rather remarkable that neither among Cope's specimens, nor those of Crook, nor those belonging to myself is there present an example of the premaxilla. Yet the surface of the maxilla indicates plainly that a premaxilla was applied to it, just as in *Xiphactinus* and *Ichthyodectes*. I do not see that it was relatively any smaller than in the two genera just mentioned, although it was doubtless much thinner.

While the skull in my possession is considerably crushed, and somewhat distorted, I am able to say with some confidence that the alisphenoids and orbitosphenoids were present and that they were quite as extensive bones as they were in *Xiphactinus*; but better specimens are needed in order to demonstrate their characters.

There seems to have been a nasal. As such I interpret a bone which is four or five times as long as wide, which lies mesiad of the nasal cavity and which articulates in front with the large ethmoid, while mesially it joins in part the ethmoid, but principally the outer border of the frontal.

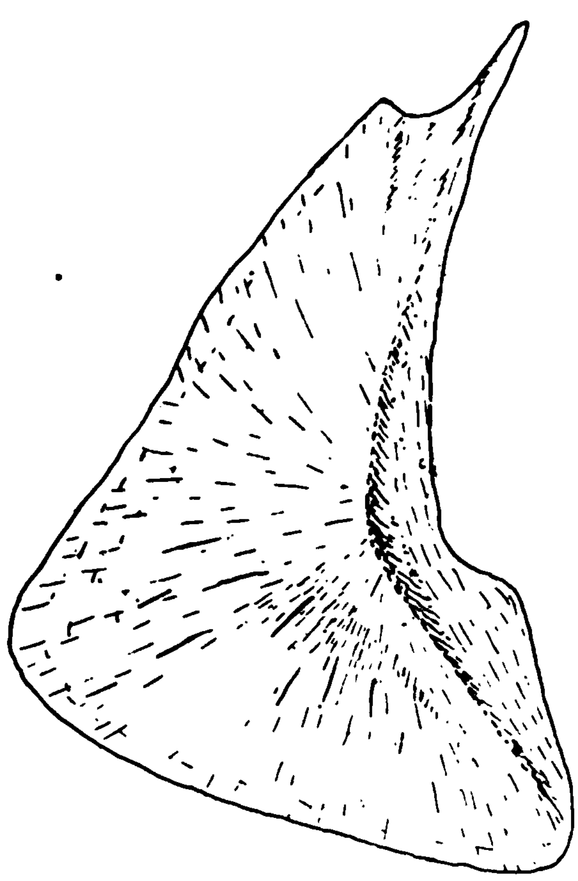
Crook has figured a portion of the lower jaw. The depth of this jaw in comparison with the maxilla is much greater than in the typical species of *Ichthyodectes*. The mandible appears to possess the same composition as that of *Xiphactinus*, viz., a dentary, an autarticulare and a dermarticulare, although it is possible that the two latter are consolidated. I am not able to find a distinct angulare. The cotylus for the quadrate is situated on the inside of a broad process, as in *Xiphactinus*. In my possession is the mandible of a large specimen of *Gillicus*, to the inner surface of which are appressed the hyoidean bones and the gill-arches. The hyoids and the gill-arches are so confused that not much can be determined regarding them. The hyoids were, however, very broad. A portion of a gill-arch displays an armature of small teeth. The gill-rakers were numerous, long, flat and wide, resembling those of *Tarpon*. Some of them are 48^{mm} long and, at the base, 5^{mm} wide. They were furnished with an armature of small teeth. The gill-rakers of the anterior arch were evidently more rigid than the

others. The hyomandibular seems to have had on its inner face a deep excavation, somewhat like that which I have described in the case of *Xiphactinus* (Zoolog. Bulletin, vol. i).

I have not enough of the vertebral column well preserved to enable me to determine its characters in this genus. It was doubtless much like the vertebral axis of *Ichthyodectes* and *Xiphactinus;* most of the vertebræ possess one or two deep grooves in each lateral surface. The upper arches were not coössified with the bodies of their vertebræ. Their bases occupied nearly the whole length of their centra; and evidently they came into contact in front and behind with the preceding and the succeeding arches. That there were anywhere in the vertebral column accessory pieces entering into the construction of the upper arches, such as I have described in *Xiphactinus*, I cannot affirm, but their presence seems probable.

On a block of soft limestone in my possession there occur a maxilla, a preopercle and several scales of an individual of this genus. The palatine condyle of the maxilla is relatively short, has a notch in its posterior end, and is separated from the anterior condyle by a space equal to two-thirds the length of the palatine condyle. A drawing of the preopercle, two-thirds the natural size, is here presented (fig. 5). The scales were relatively very large. Judging from the size of the maxilla, the fish could not have exceeded 60^{cm} (2 feet) in length. Nevertheless, one of the scales has a height of 44^{mm}. The imbedded portion of the scale is marked by grooves which radiate from the center of the scale and which are separated by spaces wider than themselves. The exposed portion of the scale appears to have been covered with numerous sharp points, which must have given a roughness to the whole body. These points were largest just behind the center of the scale. Toward the hinder edge they became smaller, and here the scale became striated with narrow grooves and ridges. It seems not unlikely that the free edge of the scale was pectinated, as in *Brevoortia.*

5 × ⅔.



U. S. National Museum, Washington, D. C.

Art. XXIV.—*On the Determination of Manganese as the Pyrophosphate*; by F. A. Gooch and Martha Austin.

[Contribution from the Kent Chemical Laboratory of Yale University—LXXIII.]

For the estimation of manganese in a gravimetric way when accuracy is a consideration, recourse is usually taken to the excellent method of Prof. Wolcott Gibbs.* This method consists in the precipitation of a manganous salt by an alkaline phosphate, the conversion of the tribasic phosphate into the ammonium manganese phosphate, and the weighing of the product of ignition as the pyrophosphate.

By Dr. Gibbs' original method the orthophosphate of manganese was precipitated by hydrogen disodium phosphate in large excess above the quantity required to cause the precipitation. The flocky white precipitate was dissolved either in sulphuric or hydrochloric acid, and precipitated again at the boiling temperature by ammonia in excess. This semi-gelatinous precipitate on boiling or long standing even in the cold becomes crystalline, the crystals forming beautiful talcose scales which have a pearly luster and a pale rose color. The precipitate was filtered off, washed with hot water, dried and ignited. The results obtained by Dr. Gibbs' students for the pyrophosphate accord closely with the theory.

Fresenius† showed subsequently that ammonium manganese phosphate dissolves in cold water, in hot water, and in an aqueous solution of ammonium chloride [1:70] to the extent of 1 part in 32,000, 1 part in 20,000, and 1 part in 18,000, respectively. It is clear, however, that the solubility of this precipitate is not indicated necessarily by the proportions given so long as an excess of the precipitant is present during the washing, though Fresenius did find in the filtrate traces of manganese which to his mind were sufficient to account for losses indicated by his test analyses, viz., one to three milligrams of oxide, or from two to six milligrams of phosphate.

Another mode of manipulation has been advocated by Blair‡ in order that the precipitate may be obtained more easily in crystalline condition. According to this method dilute ammonia is added drop by drop to the hot acid solution until the precipitate begins to form, the boiling and stirring are continued until the small amount of flocky precipitate is converted completely to crystalline condition, and the process of adding ammonia drop by drop is repeated until the manganese is all down in crystalline condition. The dilute ammonia is added in excess and the liquid filtered after cooling in ice water.

* This Journal, xliv, 216. † Zeitschrift für Anal. Chem., vi, 415.
‡ The Chemical Analysis of Iron, 106.

In discussing these methods of precipitation, McKenna* points out that both give good and accordant results, and that the process may be carried on in glass as well as in platinum, if the time of crystallization is made short enough.

When a manganous salt is precipitated in the cold by an excess of an alkaline phosphate, it falls, as Heintz† has shown, in the form of the trimanganous phosphate of the formula $Mn_3P_2O_8$. This same phosphate constitutes, as we have found, the greater part of the precipitate which forms when a manganous salt reacts in the cold in the presence of ammonium chloride with microcosmic salt and ammonia in slight excess. Boiling or even subsequent standing may, as is well known, effect a more or less complete conversion of the manganese phosphate to the ammonium manganese phosphate. Thus, in one experiment in which an amount of manganous chloride enough to produce 0·2214 grams of the pyrophosphate was precipitated in the cold by 5^{cm^3} of a saturated solution of microcosmic salt, with the subsequent addition of ammonia in excess, in a volume of 200^{cm^3} containing also 5 grams of ammonium chloride, the residue after ignition weighed 0·1904 grams. Presuming this residue to consist entirely of the pyrophosphate and the trimanganous orthophosphate, the proportion of the former to the latter calculated from the relation of symbols, and the weights taken and found, is nearly one to six. That is to say, about six-sevenths of the precipitate fell in this experiment in the form of the tribasic orthophosphate. In another experiment made exactly similarly, excepting that the liquid was heated to boiling, the proportion of the manganese pyrophosphate to the trimanganous orthophosphate in the only partially crystallized precipitate proved to be two to one. That is, in this case, two-thirds of the precipitate was in the form of the pyrophosphate. In the former of the experiments a small amount of manganese was found in the filtrate, but not enough to change materially the ratio recorded. The slight solubility appears to be connected with the incomplete conversion of the trimanganous phosphate to the ammonium manganese phosphate, for as will appear later, the manganese found in the filtrate, when the conversion is known to be nearly complete, is inappreciable unless extraordinary amounts of the ammonium salt are present. The success of the analytical process under discussion turns, therefore, upon the change of the trimanganous phosphate $Mn_3P_2O_8$ to the ammonium manganese phosphate NH_4MnPO_4. In the work to be described the attempt was made to learn the conditions under which this conversion may be best and most completely accomplished.

* Jour. Anal. Chem., v, 141. † Pogg. Ann., lxxiv, 449.

The conversion of a molecule of trimanganous phosphate to the ammonium manganese phosphate might be due, conceivably, either to the action of free ammonia or to the action of a salt of ammonium. The action of ammonia could only take place at the expense of a partial loss of manganese from the phosphate and its appearance as a hydroxide, two-thirds of the manganese going into two molecules of the ammonium manganese phosphate. In the presence of ammonium salts it is possible that the manganese oxide thus replaced might enter into union with the acid radical of the ammonium salt setting free ammonia; but if the ammonium salt present were the phosphate, or if an alkaline phosphate were present with other suitable ammonium salts, it is conceivable that the replaced manganese might appear as a constituent of a third molecule of ammonium manganese phosphate. In any event, it would be the ammonium salt and not the free ammonia which would determine the formation of the third molecule of the ammonium manganese phosphate. Plainly, too, the ammonium salt by itself, if it were a phosphate, or if a soluble phosphate were also present, might accomplish the conversion without the intermediate action of free ammonia. Unless, therefore, free ammonia favors the insolubility of the ammonium manganese phosphate, its presence would be unnecessary and might even be an actual disadvantage if the hydroxide naturally formed by its action upon the manganese phosphate were to fail to reunite fully with a phosphoric acid radical. It is plain, too, that the action of free ammonia might not stop with the replacement of one out of the three of the manganese atoms present in the molecule, but might even proceed under favorable conditions to the formation of phosphate richer in ammonium and to the separation of more manganese from its union with the acid radical. As a matter of fact Munroe* has shown that the prolonged action of hot ammonia upon the precipitate produced by the interaction of a manganous salt and an alkaline phosphate does actually produce a hydroxide which blackens as it takes oxygen from the air. Our attention has been given, therefore, more especially to a study of the conditions of action under which a salt of ammonium—the chloride—may bring about the conversion of the precipitate first thrown down by an alkaline phosphate to the form of the ammonium manganese phosphate. Experiments were made upon solutions of pure manganous chloride prepared and standardized by means of the sulphate method, as described in a former paper,† to show the effect of varying amounts of ammonium chloride on the condition of the precipitate and upon the solubility of the precipitate when

* Amer. Chemist, 1877. † This Jour. IV, v, 209.

once formed. The ammonium chloride for this work was prepared pure by boiling the chemically pure salt of commerce with a faint excess of ammonium hydrate and filtering—to free it from traces of iron, silica and alumina. In the first series of experiments dilute ammonia was added slowly to the hot faintly acidulated solution containing the manganous chloride and more than enough, theoretically, of a saturated solution of microcosmic salt to precipitate the manganese present. The liquid was heated and stirred until the flocky mass was changed to a crystalline condition. The addition of ammonia drop by drop, with constant stirring and heating, was continued until the manganese was all precipitated in crystalline form. A slight excess of ammonia was added and the liquid with the precipitate was allowed to stand for a half hour, cooling gradually or chilled in ice water. The precipitate was filtered off on asbestos under pressure, washed carefully in water made faintly ammoniacal, dried and ignited. The filtrates were tested for manganese by treatment with bromine and heating. The results of these experiments are given in the following table.

TABLE I.

$Mn_2P_2O_7$ equivalent to $MnCl_2$. Taken. grm.	$Mn_2P_2O_7$ equivalent to $MnCl_2$. Found. grm.	Error in terms of $Mn_2P_2O_7$. grm.	Error in terms of Manganese. grm.	Saturated solution of $HNH_4NaPO_4.4H_2O$. cm^3.	Total vol. cm^3.	Manganese in filtrate.
0·4033	0·3769	0·0264 —	0·0102 —	5	60*	none
0·4033	0·3728	0·0305 —	0·0118 —	5	60*	"
0·3770	0·3530	0·0240 —	0·0090 —	5	60	"
0·3770	0·3620	0·0150 —	0·0058 —	5	60	"
0·4033	0·3751	0·0282 —	0·0109 —	10	60	"
0·4033	0·3774	0·0259 —	0·0100 —	10	60	"
0·4033	0·3871	0·0162 —	0·0062 —	5	200	"
0·3226	0·3066	0·0160 —	0·0062 —	5	200	"

* Chilled in ice-water.

In this method of precipitation of the manganese in a pure solution of a manganous salt the results are all wrong. The proportion of the trimanganous phosphate to the pyrophosphate in the residue, calculated from the symbols and the weights taken and found, is in the average two to five. That is to say, five-sevenths of the trimanganous phosphate has been converted to the form of the ammonium manganous phosphate.

The precipitate obtained in this manner is white and granular but not silky, and after ignition it shows the same dead white color, and is powdery. Evidently the regulation of the volume in which the precipitation is made is not essential, and the chilling of the liquid is of no importance in changing the

manganese to the ammonium manganese salt under the given conditions. It is plain, moreover, that the assumption of a crystalline condition can not serve as an indication that the composition of the salt is ideal. It is to be noted, however, that the conditions obtaining here are essentially different from those in common practice; for, ordinarily, when manganese is to be determined ammonium salts are abundantly present as the result of previous steps in analysis.

TABLE II.

$_2O_7$ equiva- o the $MnCl_2$. m. grm.	Found. grm.	Error in terms of $Mn_2P_2O_7$. grm.	Error in terms of Manganese. grm.	Saturated solution of $HNaNH_4PO_4.4H_2O$. cm^3.	NH_4Cl. grm.	Total vol. cm^3.	Time of standing cold. hrs.	Manganese in the filtrate.
				A.				
12	0·1520	0·0022—	0·0008—	5	5	200	15	none
12	0·1540	0·0002—	0·0000—	5	10	200	15	"
12	0·1536	0·0006—	0·0002—	5	10	100	5	"
12	0·1535	0·0007—	0·0002—	5	20	200	2½	"
70	0·3712	0·0058—	0·0022—	5	20	200	½	"
70	0·3724	0·0046—	0·0018—	5	20	200	½	"
34	0·3069	0·0015—	0·0006—	5	40	200	1	"
34	0·3060	0·0024—	0·0009—	5	40	200	1	"
34	0·3059	0·0025—	0·0009—	5	40	200	15	trace
34	0·3057	0·0027—	0·0010—	5	60	200	15	none
				B.				
12	0·1521	0·0021—	0·0008—	5	10	100	40	none
12	0·1512	0·0030—	0·0010—	5	10	200	40	"
12	0·1532	0·0010—	0·0003—	5	20	200	15	"
12	0·1531	0·0011—	0·0004—	5	20	100	15	"
70	0·3720	0·0050—	0·0019—	5	20	200	½	"
70	0·3745	0·0035—	0·0014—	5	20	200	½	"
				C.				
12	0·1519	0·0023—	0·0009—	5	15	200	..	none
12	0·1530	0·0012—	0·0004—	5	20	200	..	"
12	0·1525	0·0017—	0·0007—	5	30	200	..	"
34	0·3020	0·0064—	0·0025—	5	10	200	..	"
34	0·3053	0·0031—	0·0012—	5	20	200	..	"
34	0·3033	0·0051—	0·0020—	5	20	200	..	"
34	0·3039	0·0045—	0·0017—	5	60	200	..	trace

In the experiments of the next series the conditions are varied simply in this respect, that ammonium salts are introduced before the precipitation. The precipitate was less granular and more silky. After ignition the mass was white with a faint rose color. In the experiments of section A of the table the preci-

pitate first thrown down was redissolved, reprecipitated and filtered after cooling; in those of section B, the precipitate was filtered after cooling without resolution and without reprecipitation. and in those of section C, the first precipitate was filtered at once while the solution was still hot. The length of digestion before filtering and the indications of manganese in the filtrate are recorded in the table.

It was observed in these experiments that when the amount of ammonium chloride is present in considerable quantity a fine crystalline condition is got much more readily than when the amount of that salt is small: with maximum amounts of ammonium chloride the change from the flocky to the crystalline condition is almost immediate; even in the cold the change takes place to a marked extent in a few seconds. No manganese was found in the filtrate by boiling with bromine and ammonia—a test which is capable of indicating 0·0001 grams of manganous sulphate in 500^{cm^3} of water containing 60 grams of ammonium chloride—until the ammonium chloride amounted to 20 per cent of the mass, or to 40 grams in 200^{cm^3} of the liquid, and even then but once in three trials: even when the proportion was 30 per cent—60 grams in 200^{cm^3}—the solvent action of the ammonium chloride upon the manganese salt was trifling. The pyrophosphate residues obtained in these experiments, as well as in all those recorded in this paper, were dissolved in nitric acid and tested for contamination by a chloride; in no single case did silver nitrate produce more than an inappreciable opalesence in the solution. It is plain, therefore, that the variations of the results from theory are occasioned by variation in the degree of conversion of the trimanganese phosphate to the ammonium manganese phosphate, and that, while the ammonium chloride shows no appreciable solvent action on the precipitate in the presence of the precipitant, its effect in the process of conversion is plainly evident. For the smaller amounts of the manganese salts (equivalent to 0·1542 grams of the pyrophosphate) the effect of the ammonium chloride reaches a maximum when that salt amounts to 10 per cent of the solution; for twice that amount of manganese salt, the best results were obtained by doubling the amounts of ammonium chloride. Either line of treatment yields under the most favorable conditions, results which are passably good, but the advantage inclines slightly to the first method in which the first precipitate was dissolved and reprecipitated while the liquid was cooled before filtering.

In Table III are recorded results obtained by precipitating the cold acid solution of the manganese salt and the microcosmic salt with a strong excess of ammonia. The mixture was heated to boiling for from five to ten minutes and filtered hot.

In this series of determinations the amount of ammonium chloride present was constant while the volume of the liquid present was varied and the amounts of the microcosmic salt.

TABLE III.

$Mn_2P_2O_7$ equivalent to $MnCl_2$. Taken. grm.	Found. grm.	Error in terms of $Mn_2P_2O_7$. grm.	Error in terms of Manganese. grm.	Saturated solution of $HNaNH_4PO_4.4H_2O$ cm³.	NH_4Cl. grm.	Total volume. cm³.	Manganese in the filtrate.
0·2214	0·2202	0·0012—	0·0005—	5	20	200	none
0·2214	0·2202	0·0012—	0·0005—	5	20	200	"
0·2214	0·2191	0·0023—	0·0009—	5	20	200	"
0·2214	0·2191	0·0023—	0·0009—	5	20	300	"
0·2214	0·2191	0·0023—	0·0009—	5	20	300	"
0·2214	0·2185	0·0029—	0·0011—	10	20	200	"
0·2214	0·2186	0·0028—	0·0010—	20	20	300	"
0·2214	0·2192	0·0022—	0·0009—	20	20	300	"

These results are possibly a trifle less satisfactory than those obtained for the smaller amounts of manganese by the method of Table II, it may be because the prolonged boiling tends to form a trifling amount of free oxide; but the fact is disclosed that an increase of the microcosmic salt is without influence and that a variation in volume from 200^{cm^3} to 300^{cm^3} is the occasion of little change in the indications of the process.

In another series of experiments the solution of manganous chloride was added drop by drop to the mixture of microcosmic salt and ammonium chloride made alkaline with ammonia. The precipitate which fell in the cold was crystallized by boiling the mixture a few minutes. The results are given below:

TABLE IV.

$Mn_2P_2O_7$ equivalent to $MnCl_2$. Taken. grm.	Found. grm.	Error. grm.	Error in terms of Manganese. grm.	Saturated solution of $HNaNH_4PO_4$. cm³.	NH_4Cl. grm.	Total volume. cm³.	Manganese in filtrate.
0·1542	0·1521	0·0021—	0·0008—	5	5	200	none
0·2214	0·2203	0·0011—	0·0004—	5	10	275	"
0·2214	0·2192	0·0022—	0 0009—	5	15	275	"
0·2214	0·2197	0·0017—	0·0007—	5	20	275	"
0·2214	0·2223	0·0009+	0·0003+	5	20	200	"
0·1542	0·1528	0·0014—	0·0005—	5	30	275	"

The experience of this series of experiments demonstrated again that the ease with which the flocky precipitate is converted to the crystalline ammonium manganese phosphate is

proportioned to the ammonium chloride present, and the mean error of the results for the phosphate when the ammonium chloride reached 20 grams—0·0007 grm.—is considerably less than the mean error —0·0018 grm.—when the amount of the ammonium salt was less than 20 grms.

Experiments were also made according to the modifications suggested by Munroe,* viz., the boiling of the manganous salt with an excess of microcosmic salt until the precipitate becomes crystalline and just neutralizing with dilute ammonia; but we have been unable to find the conditions of this treatment by which uniform results may be obtained in even moderate agreement with the theory.

We have tried also the effect of substituting ammonium nitrate for ammonium chloride in the conversion process; but, so far as our experience goes, the nitrate is not so effective weight for weight in producing the change of the trimanganous phosphate to the ammonium manganese phosphates, while the solubility of the product in the solution of the ammonium nitrate becomes appreciable more rapidly with the increase of the amount present than is the case when the ammonium salt is the chloride.

In the light of the experiments described it would seem to be reasonable to expect the best results from the phosphate method for determining manganese when the conditions are so arranged that precipitation may take place in the cold solution in the presence of but little free ammonia, and of enough ammonium chloride to bring about the rapid conversion of the precipitate to the crystalline condition. Under such circumstances it should be possible to secure the conversion of the phosphate to the ideal constitution as completely as possible without danger of subsequent decomposition by the prolonged action of the hot free ammonia. In carrying out this idea, the solution of manganese chloride was treated as before with microcosmic salt and a large amount of ammonium chloride, the precipitate first formed was redissolved in hydrochloric acid and precipitation again brought about by the very careful addition of dilute ammonia in slight but distinct excess. The mixture was heated only until the precipitate became silky and crystalline, when it was allowed to stand and cool for a half hour. The precipitate was filtered off upon asbestos in a perforated platinum crucible under pressure, ignited and weighed. Table V comprises the results of experiments made in this manner. In those of section A the precipitation was made in platinum vessels; in those of section B the treatment was in glass.

* Loc. cit.

Table V.

A. In Platinum.

$Mn_2P_2O_7$ equivalent to MnO_2. Taken. grm.	Found. grm.	Error in terms of $Mn_2P_2O_7$. grm.	Error in terms of Manganese. grm.	Saturated solution of $HNaNH_4PO_4$. cm³.	NH_4Cl. grm.	Total vol. cm³.	Manganese in the filtrate.
0·1885	0·1903	0·0018+	0·0007+	5	20	200	none
0·1885	0·1910	0·0025+	0·0010+	5	20	200	"
0·1885	0·1913	0·0028+	0·0011+	5	20	200	"
0·1885	0·1911	0·0026+	0·0010+	5	20	200	"
0·3770	0·3776	0·0006+	0·0002+	5	20	200	"
0·3770	0·3773	0·0003+	0·0001+	5	20	200	"
0·3770	0·3778	0·0008+	0·0003+	5	20	200	"
0·3770	0·3783	0·0013+	0·0005+	5	20	200	"
			B. In Glass.				
0·1885	0·1904	0·0019+	0·0007+	5	20	200	"
0·1885	0·1898	0·0013+	0·0005+	5	20	200	"
0·3770	0·3767	0·0003−	0·0001−	5	20	200	"
0·3770	0·3784	0·0014+	0·0005+	5	20	200	"

In this series of experiments the mean indication is, for the first time, in excess of the theory. Previously the error has been one of deficiency, and that in proportion to the amount of manganese handled, no doubt because the amount of unconverted trimanganese phosphate is proportioned to the entire amount of the phosphate. The positive error which is developed in this last series of determinations is probably due to the appearance of the natural error of all precipitation processes—viz., the tendency on the part of the precipitate to include matter in solution. In the previous experiments this effect was doubtless obscured by the incompleteness of the conversion of the trimanganous phosphate to the ammonium manganese phosphate. Indeed it is quite possible that even in the last determinations the conversion is not absolute, and that this is so suggested by the fact that the errors of excess are larger in the case of the smaller amounts of manganese for which the conversion throughout the entire work has appeared to be more complete. From the consideration of the results tabulated and described it would seem to be obvious that not only is the presence of ammonium chloride not objectionable in this analytical process, which depends upon obtaining the ammonium manganese phosphate from the trimanganese phosphate precipitated from a pure solution of manganese, but that its presence in not too small amount, or that of a substitute, is absolutely essential to make this conversion complete. For a given amount of manganese and a given volume of solution it

seems essential that the amount of ammonium chloride should reach a certain limit. According to our experience the proportion of ammonium chloride to the pyrophosphate should be at least 50 : 1 ; or, speaking approximately, more than 200 molecules of ammonium chloride must be present in the liquid 100^{cm^3} or 200^{cm^3}) to every molecule of the ammonium manganese phosphate to be formed. However, the quantity of the ammonium salt may be increased almost to the point of saturation of the liquid without causing more than a trifling solubility of the ammonium manganese phosphate in the presence of an excess of the precipitant. The statement of Fresenius and Munroe that ammonium manganese phosphate is soluble in ammonium chloride does not hold if there is an abundance of the soluble precipitating phosphate present. Further, our experience goes to show that the precipitate may be washed with perfect safety with pure water as well as with slightly ammoniacal water, or with ammoniacal water containing ammonium nitrate, if the filtration is performed rapidly and the precipitate is gathered in small space, as is the case when the phosphate is collected on asbestos in a perforated crucible. The finely granular precipitate which may be obtained by slow action of dilute ammonia added gradually to the hot solution of the manganese salt apparently includes a portion of unconverted phosphate which resists the replacement of the manganese by ammonium. On the other hand, the precipitate of flocky condition thrown down in the cold passes easily to the silky and crystalline condition when heated with the proper amount of ammonium salt and possesses a constitution approaching the ideal under such conditions. The conversion of the flocky manganous phosphate is so rapid that the precipitation may be carried on safely in glass vessels. If the ammonium chloride in the solution were to be included in the precipitate it would volatilize entirely during the ignition, leaving no trace unless, possibly, a portion of its chlorine were to combine with the manganese. Tests for chlorine in the residue of pyrophosphate resulted negatively—no more than a mere trace being found in any case, so that the contaminating effect of the ammonium chloride proves to be insignificant and the responsibility for the increase in weight above the theory must apparently rest with the included microcosmic salt.

In the practical determination of manganese by the phosphate method of Dr. Gibbs, therefore, we advocate strongly the presence of large amounts of ammonium chloride. Good results may be obtained by the method of precipitation originally laid down by Dr. Gibbs, or by the modification proposed by Blair, if the ammonium salt is present in sufficient quantity. On the whole trustworthy results are obtained most easily and

surely, according to our experience, by following the method of the experiments of Table V. The slightly acid solution, containing in a volume of 200^{cm^3} (in platinum or glass) an amount of manganese not more than enough to make 0·4 grm. of the pyrophosphate, 20 grm. of ammonium chloride and 5 to 10^{cm^3} of a cold saturated solution of microcosmic salt, is precipitated in the cold by the careful addition of dilute ammonia in only slight excess. The mixture is heated until the precipitate becomes silky and crystalline, the whole is allowed to stand and cool a half hour, the precipitate is collected upon asbestos in a perforated platinum crucible, washed (best with slightly ammoniacal water), dried at gentle heat and ignited as usual. By this process determinations of the larger amounts of manganese—0·4 grm. of the pyrophosphate—approximate rather more closely to the theoretical values than do those of the smaller amounts—0·15 grm. In either case the average error should not exceed 0·0010 grm. in terms of manganese.

ART. XXV.—*An Occurrence of Dunite in Western Massachusetts*;* by G. C. MARTIN.

Introduction.—The occurrence of a mass of dunite in the Green Mountain region of Massachusetts is of interest and importance because it is a feature of the geology of that region which has apparently been hitherto overlooked, because there are on record only two other true dunites in North America, and because its mode of occurrence is such as to leave little doubt of its eruptive origin.

Location and Topography.—The rock occurs on the mountain south of Cheshire. This mountain is a spur of the Hoosac Range and although it is in the territory discussed by Wolff in his "Geology of Hoosac Mountain"† it is topographically distinct from the main mass of that range. This is shown on the contour maps, but is much more distinctly shown in the view from some of the neighboring peaks. The exact location of the dunite area may be found upon the Greylock sheet of the topographic map, or upon the geological map (Plate I) of Monograph XXIII U. S. Geol. Survey, by tracing the meridian 73° 10′ for 2¼ miles south from the village of Cheshire to its intersection with an unnamed stream. The area in question lies chiefly between this stream and Whipple Brook, the next to the southward. The main dunite mass occupies an area irregularly oval in outline and about 1000 by 2000 feet in extent. It is situated upon a flattened shoulder on the mountain-side, and is separated from the surrounding gneisses by brooks on the north and south, and by swamps on the east and west. Within the area are a number of rocky ridges 10 to 50 feet high, separated by swamps. About 400 feet northeast of the main mass is a smaller one of uncertain extent. (Loc. 351 as shown on the accompanying map.) Another exposure of doubtful relation to the main mass is east of the north end of it at Loc. 114 *c.*; while at numerous localities east and southeast of this, and northwest of the main mass at Loc. 304 the proximity of dunite is indicated by abundant fragments, some of which may be practically in place. In the banks of the Whipple Brook and at many places to the south, possible outcrops are to be seen, but since they may be merely glacial bowlders they are not mapped. Between all these and the main mass outcrops of gneiss intervene and no surface connection is visible.

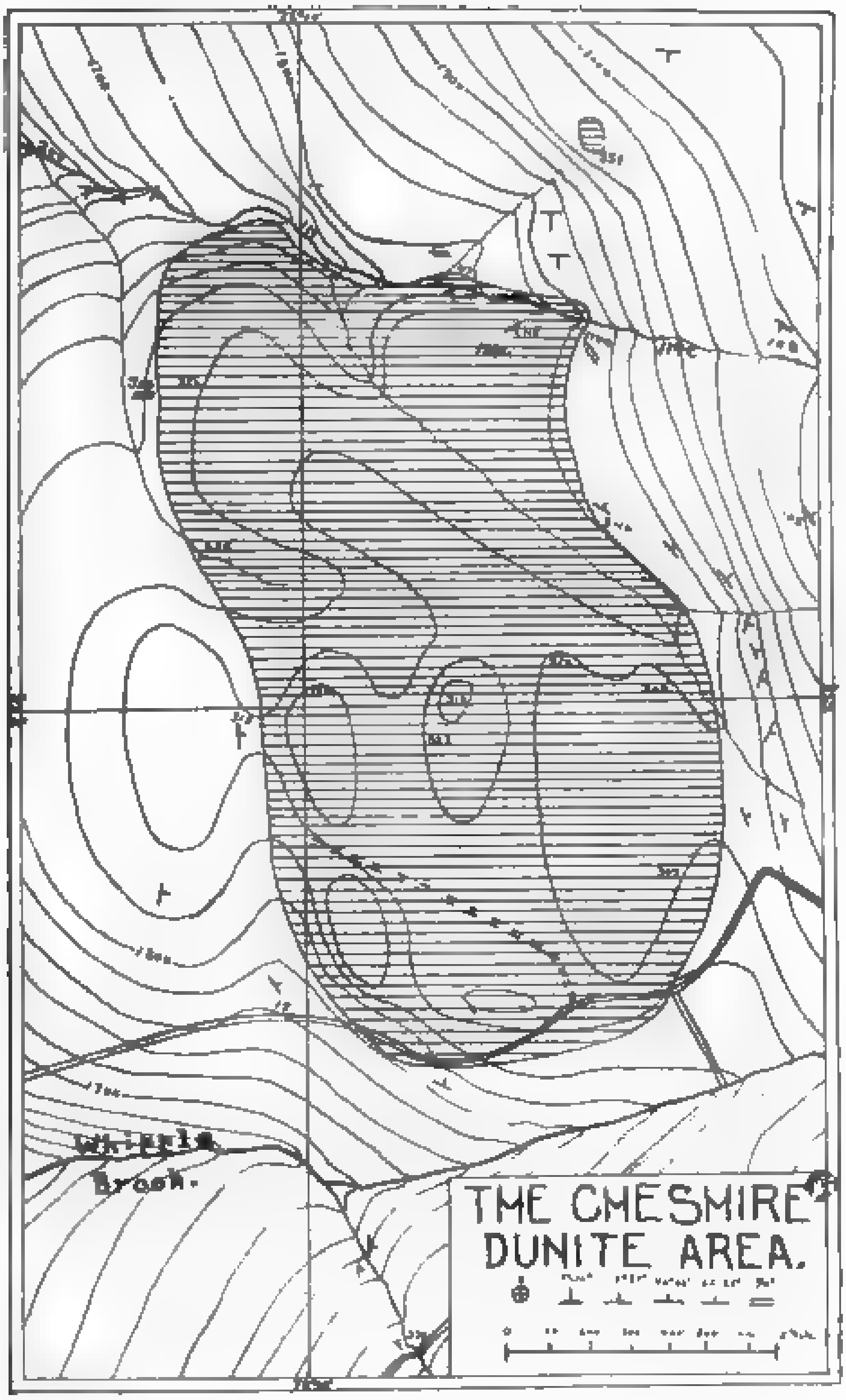
Description of Rocks.—The rocks of this area vary much in appearance; but as will be seen, the change from one form

* The author is indebted to Dr. A. C. Gill for advice and assistance in the preparation of this paper, especially in the chemical analysis, which is largely Dr. Gill's own work.

† Monograph XXIII, U. S. G. S., Part II.

to another is gradual and may be traced in the external appearance as well as in the mineralogical and structural details.

The most abundant and generally distributed form of the rock is hard, compact, and moderately fine-grained. In mass



the color is light to dark green, even approaching black, but the translucent splinters are light green usually with enough black specks to give the darker appearance. The density is from 2·9 to 3. The rock weathers readily in a well-marked zone to a yellowish brown "muscovado." This rock shows in thin section a badly shattered mass of olivine serpentinized along the cracks. Black opaque grains are scattered through it. The olivine fragments extinguish in groups, each of which

gives a uniform interference color. These groups are then the remains of former olivine crystals which are nearly uniform in size (·3 to 1^{mm}) and interlock to fill the entire field of the microscope. The cracks between the original olivines are no better developed than those between the shattered fragments. The serpentine is generally in fine cracks but often has recrystallized into needles varying in size from ·02 by ·1 to ·04 by $·5^{mm}$. These in general follow the olivine cracks. But often there is a parallel arrangement of the serpentines and sometimes a tendency for all the serpentines of an individual olivine to arrange themselves in two directions nearly at right angles, —thus giving an appearance resembling Hussak's "gestrickte Structur," but showing by the enclosed olivine its derivation from that mineral instead of from pyroxene, as is usually assumed for that form of serpentine.

A specimen of this rock was powdered and the magnetic ingredients removed. Then by means of the Thoulet solution the serpentine was floated off. There then remained olivine with black grains scattered through it. The latter came down slightly in advance of the olivine and by repeated separations pure samples of each were obtained. The black non-magnetic grains had a brown streak and gave reactions showing the presence of iron, chromium, and aluminum. They are then doubtless at least partly picotite. The magnetic grains showed a trace of chromium. An examination of the olivine showed

Color	pale green	
Sp. Gr.	3·273 (not corrected for temperature, etc.)	
Composition		
	MgO	51·41
	SiO_2	40·07
	FeO	4·84
	Al_2O_3	1·94
	CaO	----
	H_2O (ignition)	1·03
		99·29

The remaining rocks of the area range in density from 2·9 to 2·54. As the density decreases the macroscopic characters of the rock above described are gradually lost. The lightest rocks vary much from each other in texture and in color. Some are finely granular and homogeneous, some are schistose or shaly, and some are fibrous; some are black, light or dark green, yellow, white or mottled. But all grade, with the density, toward the type described above.

When these rocks are examined under the microscope it is found that the amount of olivine decreases with the density. And as the olivine decreases in amount, the serpentine increases by a gradual widening of the cracks. Recrystallization of the serpentine also takes place. Variation in rocks with the same

amount of serpentine depends in a large degree upon the amount of recrystallization and upon the relative positions assumed by these crystals. The magnetite is largely contemporaneous with the serpentine. It increases in amount with it, and shows a tendency to segregate into large grains, strings, and plates, some of several square inches in area and about ½ inch thick.

Other minerals are: hematite, with the magnetite; opal, occurring in cracks; chlorite, in irregular angular masses scattered throughout the dunite and serpentine; a carbonate, in the serpentine near the northeast corner of the main mass at Loc. 115; and a bronze non-magnetic mineral which gave the bead test for nickel and is probably niccolite, although with the quantities used no decided test for arsenic was obtained. The latter mineral is scattered in grains throughout the serpentine. The rocks of the area consist then of olivine and the serpentine which has been derived *solely* from its hydration. The original rock was a mass of olivine, with some members of the spinel group as minor constituents,—a strict *Dunite;* and it has hydrated in places to a *Dunite-serpentine.*

Field-Relations.—The olivine and serpentine are irregularly distributed, but the latter is in general more abundant around the border, especially at the northern end. Slickensides; a well marked foliation of the serpentine; and veins of fibrous serpentine traverse the area from north to south, dipping steeply to the east: but the foliation deviates from this general direction at the northern end, striking parallel to the border and dipping more moderately to the south. These characters are evidently due to shearing,—either that which accompanied the expansion during hydration, or that which attended some of the mountain-making movements by which the region has been affected. The slightly altered dunite which covers the greater part of the area has absolutely no structure but a strong irregular jointing.

The surrounding rocks are of a varied and complex character. The entire mountain was mapped by Wolff (Mono. XXIII, U. S. Geol. Survey) as "Vermont Formation (conglomerate, quartzite, and white gneiss)." The general structure is given as an overturned anticline with easterly dip and a strike varying somewhat from north. The presence of a dike of amphibolite is indicated in a position about half a mile north of the main mass of dunite.

The studies upon which this paper is based have shown that there are in the immediate vicinity of the dunite, beds of impure crystalline limestone, amphibolite, and gneiss. The limestone is apparently independent of the dunite, and it will be considered in a future detailed discussion of the entire mountain. The amphibolite is very generally distributed; is usually at least, interbedded with the gneiss; and the two are

extremely contorted. There is a general tendency toward a north and south strike with a steep easterly dip, but this varies extremely, as may be seen by the map. The dunite mass in its southern part is parallel to the strike of the gneiss, but at the northern end the bedding of the gneiss changes position, possibly forming a synclinal fold whose axis is cut by the dunite.

The contact of serpentine or dunite with gneiss is nowhere revealed. Outcrops of the two rocks are everywhere separated by eighty feet or more of swamp or by a drift-filled stream bed. In these places abound fragments of rotten gneiss and vesicular bowlders of gneiss, which latter are seldom elsewhere seen.

Structural Relations.—Concerning the structural relations of the dunite to the surrounding rocks, there are five hypotheses which may be considered.

1. That the dunite is a chemical deposit.
2. That it is a clastic.
3. That it is a bedded flow.
4. That it is a knob older than the gneisses and about which they were deposited.
5. That it is an intruded mass.

Of these the last seems best to accord with the following facts.

The unaltered dunite is uniform in character, has no trace of fragmental material, of recrystallization, or of bedding or banding of any kind.

There are an abundance of angular chloritic masses near the border, which on account of their aluminous character are probably the remains of feldspathic inclusions.

There are a number of outlying masses of dunite which can be connected with the main mass only as apophyses.

At several places the strike of the gneiss is directly toward the mass and in close proximity to it. (See map; east side, Loc. 346, 114*a*; west side, Loc. 353). These show conclusively that the dunite is discordant with the bedding of the gneiss.

The contact is deeply disintegrated and is marked by the presence of vesicular gneissoid bowlders, suggesting an alteration by an intruded mass.

Note.—In this connection it may be noted that there are in the Hoosac Range and to the east of it a considerable number of serpentine beds, many of which are not known to have been studied since the Hitchcock Survey and whose origin has not been made out. Some of them, however, are known to be derived from peridotites,* but these peridotites resemble all others in America, except those from Quebec, North Carolina, and the one here described, in containing, as original constituents, other ferro-magnesium silicates in addition to olivine.

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* Bulletin 126, U. S. Geol. Survey, pp. 10, 56, 152.

ART. XXVI.—*The Origin and Significance of Spines: A Study in Evolution;* by CHARLES EMERSON BEECHER.

[Continued from page 136.]

Summary of Causes of Spine Genesis.

Before taking up in more detail the various causes of spine development, and illustrating them by means of examples drawn from a number of classes of organisms, it is well to restate the factors which are believed to induce spine growth. This is especially desirable from the fact that, through the operation of unlike forces, similar conditions may produce the same morphological results, as in the differentiation of ornamental lamellæ and ridges, which, either from external stimuli or dispersion of growth force, may develop into spines. In such cases, it is difficult or impossible to distinguish the primary force, and the only satisfactory method is to discuss the subject under one head.

By carrying out this plan, and indicating the instances where the causes may replace or overlap each other, it may be shown how spines have originated, as follows:—

I. In response to stimuli from environment acting on most exposed parts. (A_1.)
II. As extreme results of progressive differentiation of previous structures. (A_2, B_3.)
III. Secondarily, as a means of protection and offense. (A_3, B_4, C_4, D_3.)
IV. Secondarily from sexual selection. (A_4, B_4, C_4, D_3.)
V. Secondarily from mimetic influences. (A_5, B_4, C_4, D_3.)
VI. Prolonged development under conditions favorable for multiplication. (B_1.)
VII. By repetition. (B_2.)
VIII. Restraint of environment causing suppression of structures. (C_1.)
IX. Mechanical restraint. (C_2.)
X. Disuse. (C_3, D_2.)
XI. Intrinsic suppression of structures and functions. (D_1.)

To illustrate the various causes of spine growth, representative examples which are believed to conform to the requirements will be selected from various groups of organisms. The number of spinose forms is so great that it will be impossible to give more than the briefest citation of a few of the leading types, especially those which have come under the notice of the writer; on this account the number of examples derived from the vegetable kingdom will be necessarily few.

I. *In response to stimuli from the environment acting on most exposed parts.* (A_1.)

The action of external stimuli falling on the most exposed parts of organisms is probably one of the most fundamental and fertile causes of spine production, since the relation between cause and effect is more direct and apparent here than by other modes of origin. In a general way, it comprehends all the remaining causes coming under the head of external stimuli, but for present purposes, it will be restricted by the elimination of secondary conditions, such as the indirect production of spines through differentiation of previous structures, and the action of external forces of selection.

The ruling forces in plants being so largely vegetative, or those of growth, and the cause of variation being principally physico-chemical and not molar, most of the modifications to produce spines will fall under other categories of origin (B, D) than the one now under discussion.

In the free swimming forms, however, as the Desmids and Diatoms, the external relations are found to be very much like those of animals. The frustrule of the Diatom, *Attheya decora*,[47] is quadrate in outline, and from the angles there extend sharp spinous processes, as represented in figure 32. The frustrule of the Desmid, *Staurastrum cuspidatum*, is composed of two triangular halves, and the spines project from the vertices of the angles. Other species of *Staurastrum*, *Xanthidium*, (*X. armatum*[47]), *Arthrodesmus* (*A. octocornis*[47]), etc., show similar spine growth from the most prominent portions of the frustrules. It is evident that in forms like these having angular outlines, any growth produced by external stimuli will naturally be greatest at the points of these angles, and in conformity with the previous analyses of these factors, a spiniform extension of the tissues would result.

Among the fresh-water Rhizopoda belonging to the Protoplasta (= *Amœbina*), the genus *Difflugia* affords good examples. *D. globulosa*[41] has a nearly spherical shell. In *D. pyriformis*,[41] the shell is elongate pear-shaped, and generally round on the summit or fundus, though in rare instances a central spiniform elevation is developed. This tendency becomes fixed in *D. acuminata*[41] in which the shell in general form resembles the preceding species, but the fundus is commonly prolonged into a single acuminate process (figure 33), though occasionally two or three spines are found. In *D. corona*,[41] there is a circlet of spines around the margin of the fundus besides the primary one in the center. *Difflugia constricta*[41] is a variable form, with the top of the shell generally smooth, though sometimes it is acuminate, and occasionally it has two or even a cluster of spines (figures 34–36). *Euglypha mucronata*[41] has a terminal spine, as in *Difflugia acuminata*.[41] *Placocista spinosa*[41] is a

flattened miter-shaped form with a distinct edge, along which are numerous spines. It should be noted that no spines are developed on any portion of these fresh-water Rhizopods except those here mentioned.

The Nasellarian Radiolaria furnish many instances of a terminal spine from the summit of the silicious helmet or cup-shaped skeleton, as in *Eucyrtidium elegans*,[14] *Podocyrtis Schomburgki*,[14] *Tridictyopus conicus*,[20] *Cornutella hexagona*,[20] etc. Many of the primary, or axial, spines in other sub-orders probably originated according to I. In the Spumellarian forms especially, the principal spines project from the prominent portions, as in *Trigonactura triacantha*,[20] *Hymenactura copernici*,[20] *Rhopalastrum triceros*,[20] *R. hexaceros*,[20] etc. The existence of similar non-spinose species shows that the formation of spines is independent of the growth of the normal prominences, as in *Rhopalastrum malleus*,[20] *R. hexagonum*,[20] etc.

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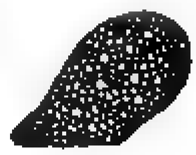

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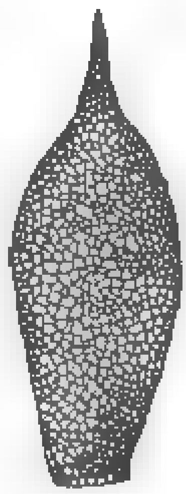

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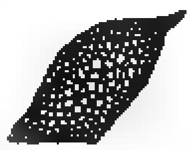

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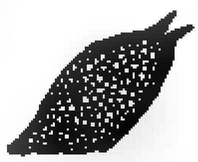

FIGURE 32. *Attheya decora*, a Diatom with spines from the angles. (From Mic Dict.)

FIGURE 33. *Difflugia acuminata*, a fresh-water Rhizopod showing spiniform projection of the fundus. × 200. (After Leidy.)

FIGURE 34. *Difflugia constricta*, a fresh-water Rhizopod, with rounded fundus. × 175. (After Leidy.)

FIGURE 35. The same, showing a single spine on the fundus. × 175. (After Leidy.)

FIGURE 36. The same, showing two spines. × 175. (After Leidy.)

In the Foraminifera, the configuration of certain forms is such that parts of the test are much more prominent than others, and in these exposed situations, the spines are most frequently developed. Some of the triangular Textulariæ have spines at the two lateral angles on the oral side. Some of the individuals of *Textularia folium*[9] show that similar spines were developed at different stages of growth, so that, in a full grown specimen, there may be two or three pairs of spines along the sides. Others, like *Verneuilina spinulosa*[9] and *Colivina pygmæa*,[9] develop spines from the points of each chamber. A number of species, also, show a single spine at the apex of the shell, as *Pleurostomella alternans*,[9] *Bolivina robusta*,[9] *Polymorphina sororia*, var. *cuspidata*,[9] etc. In the latter species, the ordinary form is rounded, or obtusely pointed at the fundus.

Some of the Infusoria have terminal spiniform processes, which, by analogy with other forms, have probably developed according to I, as *Ceratium tripos*,[9] *C. longicorne*,[9] *C. fusus*.[9]

The apertural spines on some of the Graptolites are on the most exposed portions of the hydrotheca, as in *Monograptus spinigerus*,[52] *Dicranograptus Nicholsoni*,[52] *Retiograptus tentaculatus* and *Graptolithus quadrimucronatus*. In many compound corals, the corallites are polygonal from crowding, and the most exposed portions, the angles of the calices, often bear spines, as *Favosites spinigerus*,[30] *Callopora exsul*,[30] etc. The spines on the septa and costæ of corals probably originate by intrinsic forces (B), since they are internal growths not influenced directly by external stimuli.

The spines on the ventral sacs of Crinoids are usually terminal, and in the most exposed situations; as in *Scytalocrinus validus*,[69] *Dorycrinus unicornis*,[69] *Aulocrinus Agassizi*,[69] etc.

The anterior and posterior pairs or rows of spines on the loricæ of some species of Rotatoria are in the most exposed places; as in *Anuræa squamula*, *Noteus quadricornis*, etc. The spinules on the tubes of *Spirorbis* are usually developed after it rises above the object of support so as to be exposed on all sides; as *Spirorbis spinuliferus*.[51]

The spinules at the corners of the angular cell apertures of many Bryozoa are in the most exposed situations, and probably arise through external stimuli; as in *Trematopora echinata*,[30] *T. spiculata*,[30] etc. The large marginal spines of the Brachiopod *Atrypa hystrix*[31] probably owe their excessive development to external stimuli, though the phylogeny of the species shows that the spines first originated through the differentiation of the radiate and concentric ornaments.

In many Pelecypods, the siphonal region receives a great amount of stimulus, and the post umbonal slope is the part most exposed. Along this slope are found many of the spines, and generally the greatest differentiation of ornament. Examples of spines on post-umbonal slopes may be seen in *Callista sublamellosa* and young *Saxicava arctica* (figure 27). Such spines represent periodic extensions of the mantle border, and in some cases, the stimulus for this growth may come from internal causes. The spines on *Unio spinosus* and related species are believed by Mr. Charles T. Simpson to assist in anchoring the shell in the sand of swift running streams. In *Callista*, the young *Saxicava*, and the Unios mentioned, the spines occur on all individuals and at such an early period as to preclude any special sexual function.

In the Gastropoda, the periodic extension of the shell over the posterior canal and the spiniform prominences formed on the labrum are situated in exposed places, or where the amount of stimulus is greatest; as in *Trophon magellanicus*, *Strombus pugilis*, *Fusus colus*, *Clavatula mitra*, *Melo diadema*, etc.

The spines on the larvæ of geometrid moths are usually on top of the loop, and are explained by Packard[54] as follows:

"The humps or horns arise from the most prominent portions of the body, at the point where the body is most exposed to external stimuli."

When the origin and function of spines in a great many forms of animals, and especially among the higher classes, are examined, it seems almost impossible to decide whether a spine has been originated and perpetuated by free variation and heredity, or by the general action of external stimuli on the most exposed parts; and in the latter case, whether or not under the selective influences of use. Its origin in either instance may be through external stimuli, but in the latter, it falls under other captions than A_1; or, in other words, the external stimuli excite the growth force at certain points, and the growths so produced may be simply reciprocal without function or they may serve purposes of protection or offense. Thus, the dorsal and rostral spines on the zoëa of the Decapods are on the most exposed points, and seem to function as defensive structures. As soon as the legs become well developed or when the animal ceases to swim at the surface and hides among the stones, etc., at the bottom, these spines become reduced and are often succeeded by others. The spines of the adult are also usually efficient for protection, but owing to the change in form of the animal and change of habitat, the most exposed parts are different from those of the larva, and the spines are frequently developed where there were no larval spines; as in *Cancer irroratus*, *Callinectes hastatus*, etc. Again, the horned ungulates show in their habits of sport, fighting, defense, and procuration of food, that the exposed angles of the top of the skull are subject to the greatest number of stimuli, and there the horns are developed. The connection between external stimuli and growth is here most manifest, for it is impossible to imagine the action of free variation or simple growth force as resulting independently, in the evolution of horned out of hornless species in several suborders of mammals, and in every case determining the location of the horns on the prominent angles of the skull, whether on the nasals, maxillaries, frontals, or parietals.

It is well known that toads and frogs defend themselves by using the head as a shield, and the cranial angles thus receive the greatest amount of stimulus. "There are natural series of genera measured by the degree of ossification of the superior cranial walls" (Cope[10]). In the highest genera, the head is completely encased, and in some forms the projecting angles are developed into short horns. The so-called "Horned Toad" (*Phrynosoma*) has the same habit of defense, and it is believed that this mode of protection or of receiving impacts has given rise to the structure, by stimulating growth at these points.

II. *As extreme results of progressive differentiation of previous structures.* (A_2, B_2.)

The differentiation of existing ornamental structures into spines has already been noticed in several instances in this article. It was shown that spines often arise by the elongation of nodes and tubercles or similar structures, by rhythmic alternating areas of growth in lamellæ and ridges, and by the growth of matter at the intersections of lines, lamellæ, ridges, etc. Furthermore, it was indicated that this progressive differentiation could be produced either (*a*) by the direct action of external stimuli affecting the amount of nutrition brought to a certain structure, (*b*) by the stimulus and dispersion of growth force, or (*c*) by a combination of the two forces. In this differentiation of the features which are generally called "ornamental," it will also be shown that the spine is the final result of progressive differentiation and, as previously indicated, can be formed out of a variety of other structures. The term "ornamental" is mainly one of human interpretation, and is used simply in apposition to "plain" or "simple"; for example, a clam cannot be imagined as consciously favoring a particular kind or arrangement of tubercles for ornamental purposes.

In a reticulate or cancellate surface formed by the crossing of raised lines, ridges, or lamellæ, it is evident that the causes or forces producing such structures will be increased at the points of intersection, and normally the amount of growth will here be greatest. In this way, it is possible to account for the very common presence of spines at the intersections of the radiating and concentric lines on many Mollusca and other organisms.

A few examples will now be given illustrating the differentiation of various structures into spines.

The points of intersections of the elements of the lattice in the Radiolaria are where spines are most frequently found; as in *Larnacalpes lentellipsis*, *Orosphæra Huxleyi*, *Carposphæra melitomma*, etc.[26] In *Xiphosphæra pallas*, the ridges about the openings or meshes are granular, and the intersections are raised into spines. Many of the discoid shells have their edges differentiated into spines, as *Heliodiscus asteriscus*, *H. cingillum*, *H. glyphodon*, *Sethastylus dentatus*, *Heliodrymus dendrocyclus*, etc. When an edge becomes elevated and defined as a carina, this structure is also often spiniferous, as in *Tripocalpis triserrata* and *Astropilium elegans*. The final differentiation of the radiate arrangement in the Radiolaria results in forms consisting only of a composite spine, as in the legion Acantharia.

In the Foraminifera, there are many instances of the gradual differentiation of carinæ, ribs, costæ, etc., into spines. In

Bulimina aculeata,[9] the surface nodes and granules become developed into spines. In *Textularia carinata*[9] and *Cristellaria calcar,*[9] the carinæ are spiniferous. The young of *Uvigerina aculeata*[9] is strongly costate, and later shell growth shows the costæ broken up into numerous spines. A related species (*U. asperula*[9]) has the whole test covered with spinules, which are sometimes arranged in lines, showing derivation from costæ. In *Truncatulina reticulata,*[9] the carina is made up of confluent spines, often discrete along the edge, and sometimes entirely separated.

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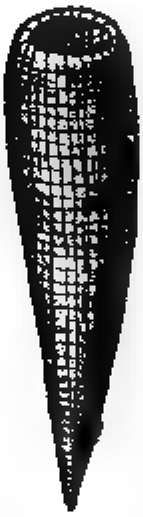

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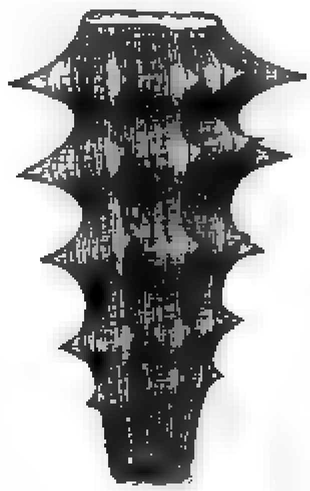

FIGURE 37.—*Cyathophycus reticulatus.* Ordovician. ½.
FIGURE 38.—*Dictyospongia Conradi.* Devonian. ½.
FIGURE 39.—*Hydroceras tuberosum.* Devonian. ½. (Figs. 37, 38, 39, after Hall.)
To illustrate progressive chronogenetic and ontogenetic differentiation in a family of hexactinellid sponges.

The hexactinellid sponges belonging to the family Dictyospongidæ show some very clear instances of the progressive differentiation of ornament in time and in ontogeny. The Ordovician *Cyathophycus reticulatus*[28] is a turbinate form, with a rectangular mesh of longitudinal and transverse spicular rays (figure 37). At more or less regular intervals, some of the spicules are larger, thus dividing the surface into larger rectangular areas. In *Dictyospongia prismatica*[28] from the Devonian, the domination of eight of the longitudinal bundles of spicules has produced a prismatic form. *D. Conradi*[28] is regularly an eight-sided pyramid or prism when young, but with the growth and elongation of the sponge, it developed slight undulations, then nodes, and later prominent tubercles (figure 38). *Ceratodictya annulata* and *Hydnoceras nodosum*[28] show a further specialization in the formation of rings and nodes. Practically the limit to these specializations is attained in *Hydnoceras tuberosum*[28] (figure 39), *H. phymatodes* and related forms. In *H. tuberosum,* the apex representing the young stage or the initial growth is much like *Cyathophycus*

or *Dictyospongia.* This is followed by a prismatic stage like *D. prismatica* and *D. Conradi*, then the nodes and tubercles are introduced and further growth produces the typical characters of the species. The tubercles are surmounted by a sharp spine formed at the intersection of two spicular laminæ, one concentric and one longitudinal.

Another type of surface specialization is shown in the genus *Physospongia* from the Keokuk group of the Lower Carboniferous. In this genus, there are bands of regular, alternating, elevated and depressed quadrules, the former frequently having the superficial layer of spicules extended into a spiniform process, as in *P. Dawsoni.*[24]

Among corals, there is occasionally some evidence of the external differentiation of structures into spines. The epitheca of the Tetracoralla frequently shows, by means of low lines or low ridges, the number and direction of the septa, and in some of the later species. these external septal lines are ornamented with rows of short spines or spinules; as in *Cyathaxonia cynodon*[18] and *Zaphrentis spinulosa.*[18]

Many Crinoids and Asteroids show the development of tubercles into spines, and the surface sculpture is often made up of ridges which bear strong spines at the points of intersection; as in *Gilbertsocrinus tuberosus,*[20] *Technocrinus spinulosus,*[20] *Actinocrinus lobatus,*[20] *A. pernodosus*, *Oreaster occidentalis*, *O. gigas*, *Retaster cribrosus*, etc.

The concentric laminæ of growth in the Brachiopods are frequently differentiated into spinules; as in *Siphonotreta unguiculata,*[21] *Schizambon typicalis,*[21] *Spirifer fimbriatus,*[21] *S. pseudolineatus,*[21] *S. setigerus,*[21] *Cliothyris Royssii,*[21] etc. Other species show the differentiation of the radii into spines; as *Acanthothyris spinosa,*[14] and *A. Doderleini.*[14] In others the strong concentric laminæ passing over radii are often infolded into spines; as in *Atrypa spinosa.*[21]

Among the Mollusca, innumerable examples could be cited showing clearly the differentiation of various ornamental features into spines. Some of these have already been discussed, but may be referred to again in this connection. Thus, an illustration of the passage of concentric laminæ into spines is shown in *Avicula sterna*[24] and *Anomia aculeata*[24] (figures 26 and 28), .and *Margaritiphora fimbriata*, etc. Many species of Gastropods show the same types of differentiation. The differentiation of radiating lines or ridges into spines is equally common, and is well shown in *Spondylus* (figures 12, 14, 30), and in *Lima squamosus* (figure 40). In

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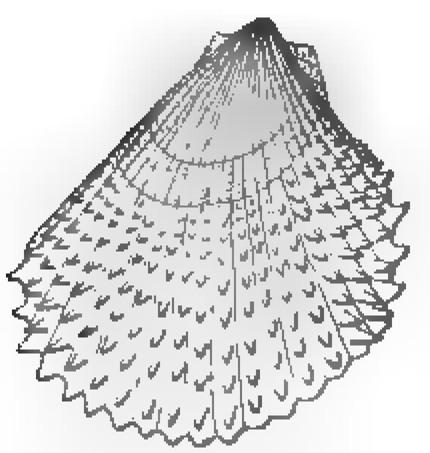

FIGURE 40. *Lima squamosus* Natural size. To show differentiation of radii into spines.

most of these cases, the rib represents the progression of a fold in the edge of the mantle, while the spine is a process of a concentric lamina, and is usually more or less flat or tubular. Occasionally, the rib becomes obsolescent, and is represented by a row of spines, as in some specimens of the Gastropod, *Crucibulum spinosum.* When the radiating and concentric ornaments are distinctly continuous, a reticulate or cancellate appearance is produced, and the points of intersection often bear spines; as in *Aviculopecten scabridus,*[29] *A. ornatus,*[29] *Actinopteria Boydi,*[29] *Pterinopecten spondylus,*[29] etc.

The raised lines or ridges on the legs and carapaces of Crustacea are frequently spiniferous, as *Gelasimus princeps*, *Gecarcinus ruricola*, etc. The radii on the shells of barnacles are sometimes differentiated into spines; as in *Balanus tintinnabulum* var. *spinosus.*[11]

In the higher animals, the differentiation of ornamental features into spines is not common, especially as most of the forms are devoid of hard external parts. Among the fishes and reptiles, certain lines and ridges on the head and body are often spiniferous, while in others the scales have spiniferous ribs.

III. *Secondarily as a means of protection and offense.* (A_8, B_4.)

After spines have originated through the stimuli from the environment acting on the most exposed parts, or by growth force, or by progressive differentiation of previous structures, they may often acquire added qualities, one of which is to protect an organism from the attacks of many of its enemies.

Morris[49] shows that defense in animals is either mechanical or motor, while in the higher plants, it is purely mechanical. The spine clearly belongs to the mechanical mode of defense, and in many animals may be efficient without motion. If motion is added, it then may serve not only for protection but for offense as well. Natural selection evidently could not originate a spine, but after one has appeared from any of the causes mentioned in the preceding paragraph, this agency could tend to preserve and allow the spine to develop along certain lines. The restrictions as a defensive structure would be those of efficiency, and therefore all the monstrous growths, vagaries, and ornamental spine features would arise independently of the action of protective selection, and would be accounted for by the operation of the forces of the environment, growth, and sexual selection. In this way, the simple antlers of the Tertiary Deer may be imagined to have reached the highest degree of efficiency as weapons, by ordinary natural selection (figure 41). In most cases, the subsequent increasing complexity of the antlers during more modern times cannot have improved their usefulness for protection or fighting

(figures 42, 43), and probably arose through gradual specialization according to the law of multiplication of effects, acted on by the agency of sexual selection. In some species, as the Reindeer (*Rangifer tarandus*), the differentiation of the antlers has secondarily produced a useful structure. One of the brow tines in this species has become greatly enlarged and palmated, and serves to assist in removing the snow to uncover food. Evidently this has had something to do with the common retention of the antlers in both sexes.

41. 42. 43.

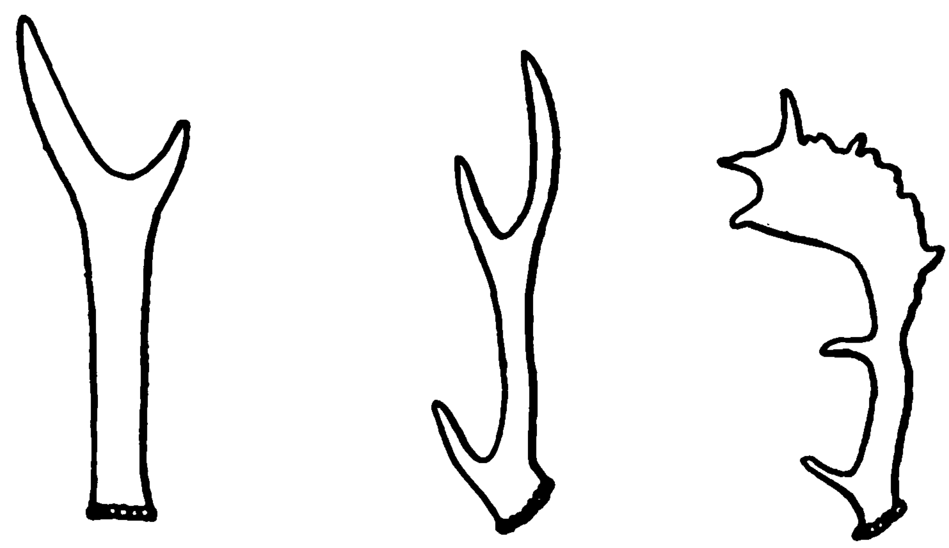

FIGURE 41. Antler of *Cervulus* (?) *dicranoceros*. Pliocene.
FIGURE 42. Antler of *Cervus pardinensis*. Pliocene.
FIGURE 43. Antler of the Fallow Deer (*Cervus dama*). Reduced. (After Nicholson and Lydekker.)

Certain types of horns are common to particular regions, especially when the cattle are in a semi-wild state, as in the Western Plains of America. The Texas cattle have long, gently curved horns standing out from the head. Similar forms are prevalent in the cattle of southern Italy and in other warm temperate regions. Farther north, the horns become more curved in a direction parallel with the head, and are therefore closer to the skull. The most northerly representative of the hollow-horned ruminants, the Musk-Ox (*Ovibos mochatus*) has the horns hanging down close to the skull and only curved outwards in their distal portions. Marsh suggests to the writer that these variations in the directions of the horns have been influenced by the climate. A warm climate permits the horns to stand out directly from the skull. Farther north, or in a colder region, the frequent freezing of the horns and their consequent drooping has induced a natural drooping condition, and an Arctic climate has resulted in the production of horns closely appressed to the skull, in which position they cannot be affected by freezing temperatures.

Another possible service for antlers is also suggested by Marsh. As is well known, the male Moose is one of the most wary of the Cervidæ, and detects noises at great distances.

The large palmate antlers act as sounding boards, and, when listening, the animal holds his ears in the focus of the anterior surfaces of the antlers.

The hollow-horned mammals afford some of the most evident examples of the use of horns for protection and offense. In species with permanent horns, like the bison, oxen, goats, cattle, antelopes, etc., the horns are generally present in both sexes, though in the males they are often much the larger. In defense, many of the horned ruminants hold the head down, thus protecting the nose and bringing the top of the skull into prominence. In this position, the horns are most effective. A similar posture is taken by the horned batrachians and lizards.

The Porcupine and Echidna rely largely on the protection afforded by their spines, and on this account they are sluggish in their movements, and make little effort to escape approaching enemies.

Many of the great horned Dinosaurs of the Mesozoic are well provided with an armature of protective plates and spines on various parts of the body. In addition to an armature on the body, *Triceratops*[46] had three large horns on the head, one median (nasal) and two lateral (supra-orbital). These were powerful offensive and defensive weapons. There were also other small nodes and spiniform ossicles around the posterior crest of the skull and on the jugals, forming a part of the general armor. In *Stegosaurus*,[42] the efficient offensive and defensive weapons were the huge spines on the tail, and it is interesting to note as a parallel to this condition, that the greatest nerve centers were in the sacrum, and therefore posterior also.

No group of vertebrates shows such a variety of protective and offensive characters as the fishes. Many of the older types were heavily plated, while in others the fin-spines were greatly developed. Among modern forms, the protective character of the spines is well shown in types like the Spiny Box-fish, *Chilomycterus geometricus* and *Diodon maculatus*. A combination of mechanical and optical protection is afforded in the remarkable Australian Pipe-fish, *Phyllopteryx eques*[25] (figure 49). This fish has numerous spines and ribbon-like branching filaments, the former giving it a mechanical defense, and the latter assisting in its concealment among sea-weeds, to which it bears a striking resemblance.

Spines for protection are extremely common among insects, even in larval forms. They have been so frequently noted as to require no elaboration here. Packard[54] has ably discussed the origin of nodes, tubercles, and spines, among certain caterpillars. Among the forms which feed exclusively at or near

the ground, he finds the body usually smooth, while those feeding on trees or on both trees and ground are often variously spined and tuberculated. These ornamental features arise from the modification of the piliferous warts common to all lepidopterous larvæ, and he concludes that the trees were more favorable for temperature, food, etc., than the ground, and that an increase of nutrition and growth force led to the hypertrophy of these warts into tubercles and spines. Having thus arisen, they immediately became useful for protection from birds and parasitic insects.

Among the Crustacea, there are also numerous examples of protective spines. These may be confined to parts of the body and legs especially exposed, or the entire animal may partake of the spiny character, as in the crab, *Echidnocerus setimanus*, where even the eye-stalks and antennæ are spiniferous. Others, like *Lithodes maia*, have the spines generally distributed over the carapace and legs. While serving for defensive purposes, this generally spinose character has probably reached its extreme development through the influence of repetition (B_3). The nauplius larva of *Lepas fascicularis* is very large, and has highly defensive spines which are explained by Balfour[3] as a secondary adaptation for protection. The larger spines on Trilobites, especially those from the genal angles and the axis, doubtless served protective purposes. The extremes of spinosity in this class are found in the various species and genera of the family Acidaspidæ, and also in many forms of *Arges*, *Terataspis*, *Hoplolichas*, etc.

Even among the star-fishes, which are so generally spinose, some forms have the spines so prominently developed on the most exposed portions of the animal that they evidently serve for protection; as *Acanthaster solaris*, *Echinaster spinosus*, etc.

The examples already given are sufficient to emphasize the fact that after spines are developed, they may then often serve for protection and offense and therefore be useful, their efficiency being controlled by natural selection resulting in the survival of the fittest.

Another process or kind of selection has been described by Verrill, as "Cannibalistic Selection." He has shown that the young of carnivorous animals often prey upon each other, as in the larval forms of some Decapoda, or sometimes even before the escape of the young from the egg capsules, as in some of the Gastropoda. Here, of course, any natural variation in the newly-hatched animals which would give an individual some advantage over its companions would tend to its preservation and to their destruction. In this way, it may occur that the relative growth of spines in the zoëa of decapods has

determined the survival of the well-armed individuals, as in the zoëa of *Cancer*[68] (figure 44), *Carcinus*, *Homarus*, etc.

44.

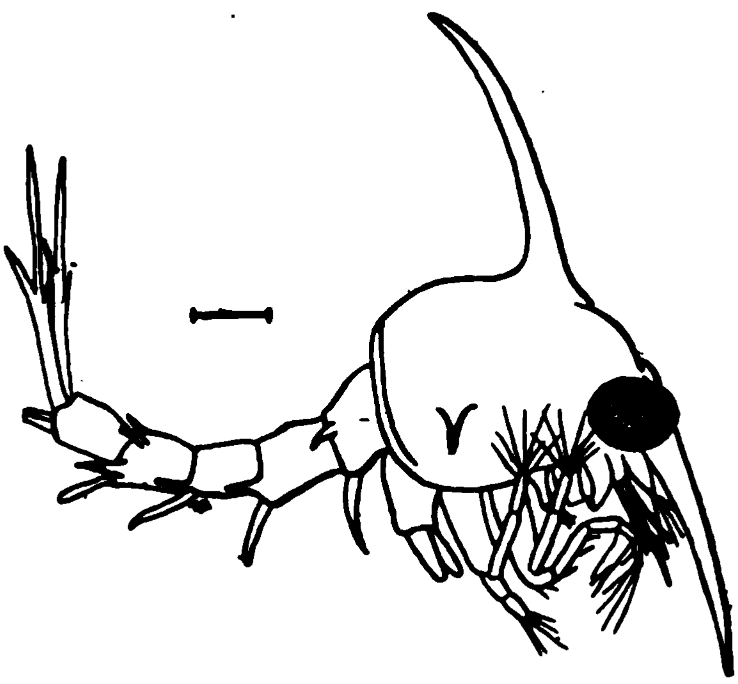

FIGURE 44. Zoëa of the common crab, *Cancer irroratus*; lateral view. × 8. (After Verrill and Smith[68].)

IV. *Secondarily from sexual selection.* (A_4, B_4.)

The males and females of so many animals present differences in size, color, and ornament, that corresponding variations in the development of spines, horns, and antlers, might naturally be expected. That such differences actually occur in nature is evident. Every gradation can be found between horns or antlers common to both sexes and those confined to one sex. Probably the initial difference is as ancient as sex itself.

Sexual variations of horns are most familiar among the mammals. Some, as the Giraffe, Ox, Bison, and Reindeer, have them present in both sexes, though the antlers of the female Reindeer are smaller and more slender than in the male, and in the American variety are sometimes absent. Others, as in the Prong-horn Antelope, many sheep, goats, etc., have the horns usually quite small in the female, and well developed in the male. Lastly, the modern Deer, Elk, Moose, etc., have the antlers confined to the males alone, the female being entirely without them.

Some of the early deer (*Procervulus*) seem to have had antlers in both sexes, and in nearly all the families of the Ruminata, there are species without horns, other species with horns in both sexes, and still others with horns only in the male. In the wild state, the presence or absence of horns and their character in any particular species seem to be well established, but in domesticated forms, the greatest variety is found. Among domesticated cattle, presumably of one species

originally, varieties are found without horns, and others with horns, showing all degrees of twisting and length.

By protecting cattle from enemies, by forcing them into changed environment, and by varying amounts of nutrition, man has evidently brought the original stock into a condition of free variation. This state has been made use of in the production of endless varieties by selection and cross-breeding.

Darwin[14] accounts for the sexual selection affecting the growth of the antlers in the Deer as due to excess in the number of male individuals, and their struggles for supremacy in the possession of a mate. The antlers at the breeding season are strong and solid, and are therefore at their maximum of efficiency in each individual. They are shed at or before the time the young are born. Previous to the growth and maturity of the new antlers, the young are so far advanced as to be able to avoid being killed by the adult males. Furthermore, Darwin suggests that the excessive development of antlers into palmate and arborescent forms was probably an ornamental character attractive to the females. These complicated antlers not being the most efficient weapons, the fighting proclivities of the males would tend to favor the individuals with simple antlers, and to repress the more differentiated forms. Thus, the two influences would be opposed to each other, though not necessarily equal. The law of the multiplication of effects may also have some force, since it may carry a structure beyond the bounds of efficiency. Even in one of the oldest horned mammals, the *Protocerus*[45] of the Miocene Tertiary, a great difference is seen in the horns of the two sexes. The female has little nodes or tubercles, which in the male rise to the height and prominence of the horns on the Giraffe, or are even relatively more pronounced.

The males of some other vertebrates have spiniform processes or spurs on their legs and wings serving particular functions. The spurs in birds are to be considered mainly as weapons which are used by the males in combats among themselves. They are developed on the metatarsal or metacarpal bones as bony processes ensheathed in horn. In the females, the spurs are generally rudimentary. A kind of spur is also found on the hind limbs of the male *Echidna* and *Ornithorhynchus*, attached to the astragalus. It is perforated by a duct leading from a gland. The functions of the spur and of the secretion are unknown.

Many lizards especially among the Chamæleons present striking differences between the sexes, and the males of some of them develop veritable horns like those in cattle, sheep, and other hollow-horned ruminants. Darwin[14] illustrates and describes a number of most interesting examples. One of

them (*Chamæleon Oweni*) is here shown (figures 45, 46). The male has three horns, one on the snout and two on the forehead. They are supported by bony excrescences from the skull. From the peaceable nature of these animals, Darwin concludes that "we are driven to infer that these almost monstrous deviations of structure serve as masculine ornaments."

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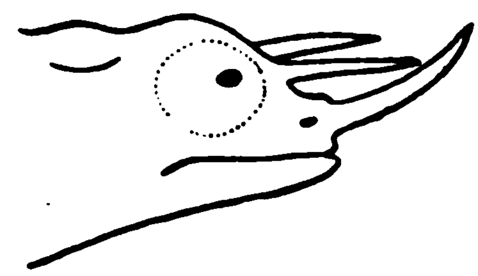

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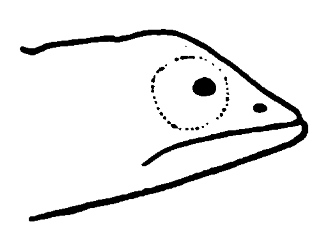


FIGURE 45. Profile of head of *Chamæleon Oweni*; male. ½.
FIGURE 46. Female of the same species. ½. (After Darwin.)

The males of the tropical American genus of fishes, *Callichthys*, "have the spines on the pectoral fins stronger and longer than those of the female, the spine increasing in size as the male reaches maturity" (Seeley[65]).

Among insects, the males of many beetles belonging to the Lamellicorns have long horns arising from various parts of the head and thorax. One of the best known forms is the Hercules beetle (*Dynastes hercules*). Bateson[5] states that, in this and other genera, it is commonly found that the males are not all alike, but some are of about the size of the females and have little or no development of horns, while others are more than twice the size of the females and have enormous horns. These two forms of male are called "low" and "high" males, respectively. Among the males, similar dimorphism in respect to size and length of horns occurs in *Xylotrupes gideon*, and in the stag beetle (*Lucanus cervus*, *L. titanus*, *L. dama*).

In many of these cases, the horns are evidently protective and not developed through the selective influences of the female. In such cases, the habits of the male are supposedly different from those of the female. Thus, Wallace[70] suggests that the horned males of the coleopterid families Copridæ and Dynastidæ fly about more, as is commonly the case with male insects, and that the horns are an efficient protection against insectivorous birds. These interpretations clearly do not come under the definition of sexual selection as restricted to the choice of either sex. Beauty, voice, or strength, may influence the selection of a mate by the opposite sex, but when the habits of the sexes are different and certain characters arise in response to this change, the explanation is then really found in the law of adaptation or physical selection.

V. *Secondarily from mimetic influences.* (A_6, B_4.)

Natural selection may aid in furthering and preserving a spinose organism after the spines have originated through any primary cause. One aspect of this influence may be treated

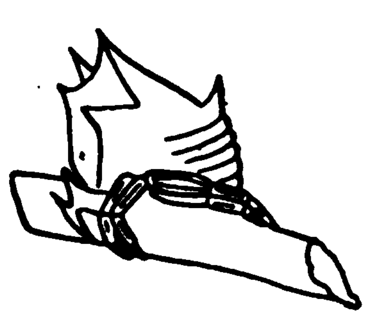
under the head of mimicry. If, by their resemblance in form, color, or voice any characters are similar to characters present in the surroundings of the animal, and afford a means of protection or are useful, they may be considered as mimetic in the broadest sense of the term. Mimicry is usually restricted to a kind of special resemblance, and not to the cases of general resemblance afforded by an animal without significant colors in general harmony with its surroundings.

The influence of mimicry in the production of spines can only occur where the object mimicked is spiniform or spinose. Apparently this is rather infrequent and of little importance as a factor of acanthogeny.

Insects and spiders have furnished the greatest number and variety of mimetic forms, both in their larval and adult conditions, and naturally would be expected to furnish examples of spines having mimetic significance. The object mimicked may be another species of insect or animal, in which case, there is usually some offensive or defensive quality rendering the resemblance useful to the mimicker; or, the whole or a portion of some plant or other object may be imitated, tending to the more or less complete concealment of the mimicking insect.

Satisfactory examples are not at hand, though doubtless many occur in nature, and some have been described, but not for the present purpose. A few will be cited here which seem to conform to the requirements.

47.



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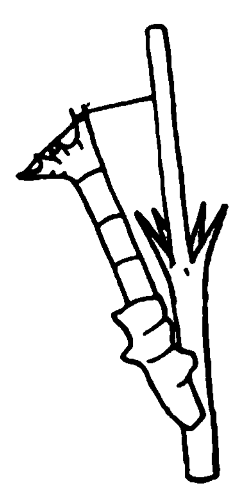


FIGURE 47.—Profile of a Spider (*Cœrostris mitralis*) on a twig mimicking a spiny excrescence. (From Peckham, after Vinson.)

FIGURE 48. The larva of the Early Thorn Moth (*Selenia illunaria*) resting on a twig; showing mimicry of stem and spiniform processes. ½. (After Poulton.)

A Madagascar spider (*Cœrostris mitralis*) is described by Elizabeth G. Peckham[56] as sitting motionless on a branch and resembling a woody excrescence with projections or spiniform processes, figure 47. Other spiny spiders of the Epeiridæ probably have similar protective mimetic features, as *Epeira spinea* and *Acrosoma arcuata*.

The larva of the Early Thorn Moth as described and illustrated by Poulton[18] bears a strong resemblance to the twig upon which it rests, even to spiniform processes, axils, and buds (figure 48). Packard[14] cites a striking case of mimicry in

49.

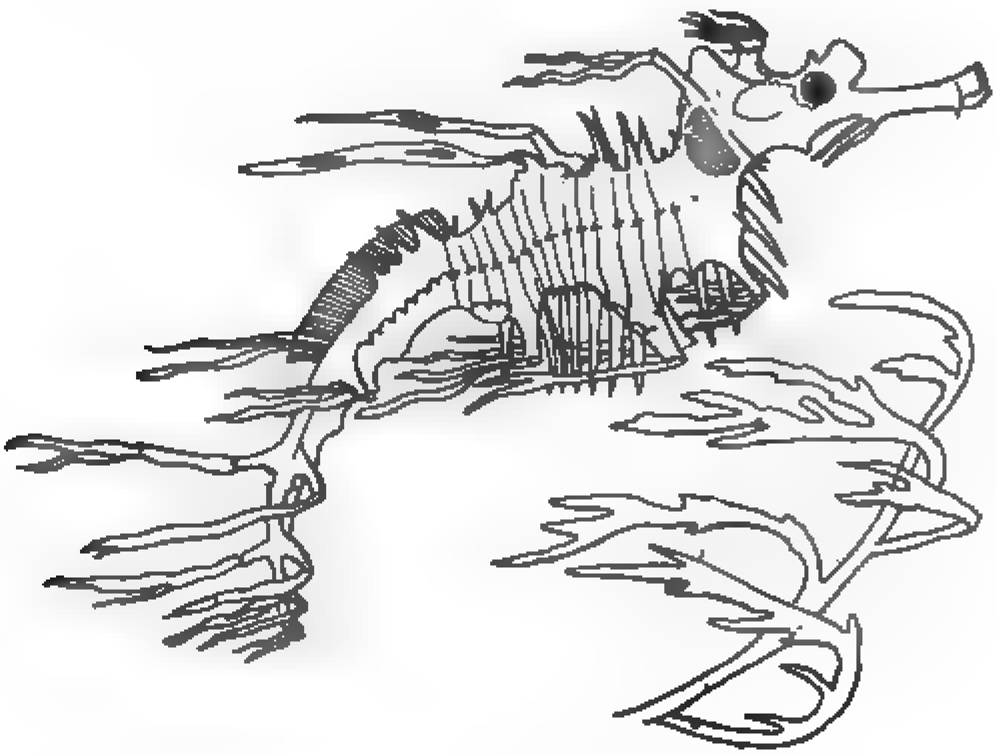


FIGURE 49. Australian Pipe-fish (*Phyllopteryx eques*) and frond of sea-weed in lower right hand corner; showing mimicry. ½. (After Günther.)

the caterpillar of another genus of moth (*Schizura*), where the spines and tubercles resemble the serrations of a leaf "so that when feeding on the edge of a leaf, the Schizuræ exactly imitate a portion of the fresh-green serrated edge of a leaf including a sere, brown, withered spot, the angular, serrate outline of the back corresponding to the serrate outline of the edge of the leaf."

The Australian Pipe-fish *Phyllopteryx*, previously mentioned under the head of spines for protection, shows the mimicry of a plant by an animal to a striking degree. This fish closely imitates a seaweed (figure 49) and Günther[15] gives the following description of the spines and filaments on the species *Phyllopteryx eques*: "There is a pair of small spines behind the middle of the upper edge of the snout, a pair of minute barbels at the chin, and a pair of long appendages in the middle of the lower part of the head. The forehead bears a broad, erect, somewhat four-sided crest, behind which there is a single shorter spine. A horizontal spine extends above each orbit. There is a cluster of spines on the occiput, and from these narrow appendages are prolonged. On the nape of the neck is a

long spine, dilated at the base into a crest, and carrying a long forked appendage. The back is arched, and on the under side are two deep indentations. The spines on the ridges of the shields are the strongest; they are compressed, are not flexible, and each terminates in a pair of short points. There is one pair of these spines in the middle of the back, and one on each of the three prominences of the abdominal outline; they terminate in flaps, which are long and forked. There are also very long compressed flexible spines without appendages, which extend in pairs along the uppermost part of the back, while a single series extends along the middle line of the belly. Small short conical spines run in a single series along the middle line of the sides, and along the lateral edges of the belly; and there is a pair of similar spines in front of the base of the pectoral fin. The tail, which is about as long as the body, carries the dorsal fin; it is quadrangular, and has sharp edges. It carries along its upper side five pairs of band-bearing spines, which terminate in branching filaments." *

The Horned Toad *Phrynosoma* bears considerable resemblance to the joints of the Prickly Pear, with which it is often associated, and it may be suggested that the likeness both in form and spinescence represents mimetic characters.

VI. *Prolonged development under conditions favorable for multiplication.* (B_1.)

The prolonged development or existence of a stock under favorable conditions for multiplication may be considered as one of the primary influences favoring the production of spines. This implies abundance of nutrition and comparatively few enemies outside of other individuals of the same or closely related species. Under a proper amount of increased nutrition, the vitality and reproductiveness of a stock are raised, and other things being favorable, it is found that the stock will give expression to what has already been described as free variation. Hypertrophy is also very apt to be one result of abundant nutrition, so that structures of little or no use may be developed, and some of them comprise certain features which are often called ornamental.

In the excessive multiplication of individuals, it is evident that there must be a great number of natural variations, and that some of these will affect the pairing of the sexes in such a manner as to accentuate and delimit certain variations. Eventually, there also comes a struggle for existence in which favorable modifications have a decided advantage. In this way, it

* The artist who copied Günther's figure for Lennis "Synopsis der Thierkunde," 3d ed., by H. Ludwig (vol. i. p. 770, 1883) connected the fish with the adjacent fronds of seaweed so as to form a single organism.

is believed that the great amount of differentiation found in some isolated stocks has been brought about. Primarily then, a favorable condition for nutrition is assumed, which is followed by excessive numerical multiplication; while the natural variations are augmented and governed by the action of reproductive divergence for which such conditions are favorable. Secondarily, these variations are subjected to the influences of cannibalistic selection, defense, offense, sexual selection, and mimicry.

In illustration of the amount of differentiation attained by a single stock under favorable conditions, the Amphipod Crustaceans, *Gammarus* and *Allorchestes*, found in lakes Baikal and Titicaca, respectively, may again be noticed.

In respect to the number of species, *Gammarus* is very sparsely distributed over the world, though in Lake Baikal alone a hundred and seventeen species have been described by Dybowsky.[17] In contrast to this, it may be mentioned that but four fresh-water species have been discovered in the whole of Norway. In Lake Baikal, all the depths explored (to 1373 meters) have furnished species. Those living near the surface are vividly colored, yet apparently make no attempts at concealment. Many of the species are also highly spinose, though not sufficiently armed to be protected from the fish. As these Crustaceans are voracious creatures, the spinose character has probably been favored by the agency of cannibalistic selection. The lake has a number of species of fish for which the Gammaridæ furnish excellent food, but the presence of a species of seal, predaceous fish, as well as the native fishermen keep the fish below the danger point, thus allowing the Gammaridæ to become very abundant.

Similarly, in Lake Titicaca, there is a wonderful specific development of a kindred Crustacean, *Allorchestes*. One of the most spinose species (*A. armatus*) is also the commonest, and according to Faxon[18] occurs in countless numbers (figure 50).

Packard[44] shows that, among certain moths, the caterpillars as soon as they acquired arboreal habits met with favorable conditions in respect to food, temperature, etc., and that as spines and tubercles arose by normal variation, such features being found useful for protection, were therefore preserved and augmented.

50.

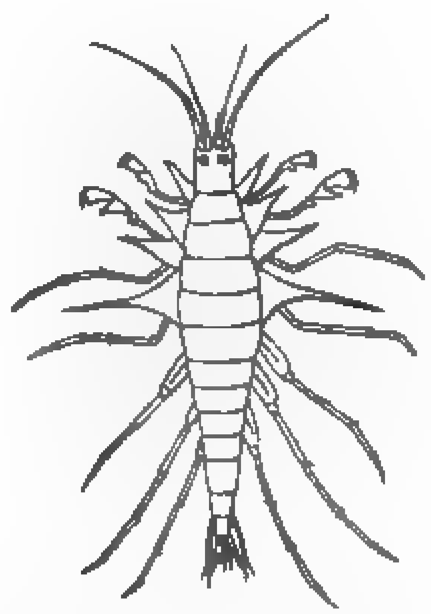


FIGURE 50. *Allorchestes armatus.* A spiny amphipod from Lake Titicaca. Female, dorsal view. Natural size = 9mm. (After Faxon.)

The differentiation of *Achatinella* has already been discussed (p. 132) as affording a striking instance of free variation among the Mollusca. The evolution of the Tertiary species of *Planorbis* at Steinheim, as described by Hyatt,[55] furnishes another example, though in neither case has the differentiation of structures proceeded far enough to result in spines. The costate form (*Planorbis costatus*) was tending toward that end, but did not attain it.

The series of Slavonian *Paludina* in the Lower Pliocene, as elucidated by Neumayr and Paul,[50] shôw a somewhat further advancement. The species in the lowest beds (typus *Paludina Neumayri*) are smooth and unornamented. Higher in the strata, they are angular and carinated, and at the top of the series, the shells are carinated, nodose, and subspinose (typus *Paludina Hœrnesi*). The living American genus *Tulotoma* is closely related to the most differentiated species (*P. Hœrnesi*), and its approach to spinose features is more pronounced.

Under the phylogeny of spinose forms (pp. 18, 19) an outline of the life history of the Brachiopod *Atrypa reticularis* and derived species was presented. This being one of the commonest types of Brachiopods in the Silurian and Devonian, often forming beds of considerable extent, it seems quite likely that its prolonged development under favorable conditions for multiplication must have had an effect on the amount and kind of variation.

It has been noticed by Brady[9] and others, that in the Foraminifera, *Globigerina bulloides*, *Orbulina universa*, etc., the pelagic forms comprise two varieties which are generally distinct, a spinous form and another with small minutely granular shells. The bottom specimens of the same species are also commonly without spines and often smaller. The interpretation seems to be that the large specimens indicate an abundance of nutrition which has also produced hypertrophy of the normal granules into spines. Some bottom specimens are large, but they are usually abnormal and of a monstrous or pathologic nature.

From the foregoing examples, the conclusion to be drawn is that, with full nutrition, there comes a numerical maximum, and naturally with this a corresponding number of normal variations. Some of these modifications, as spines, have arisen by hypertrophy. After having thus originated by growth force, they may or may not be of use for offense, defense, or concealment, or in any way give their possessor a distinct advantage.

[To be continued.]

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *A Laboratory Guide in Qualitative Chemical Analysis;* by H. L. Wells, M.A. 8vo, pp. viii, 190. New York, 1898 (John Wiley & Sons).—The purpose of the author in writing this book, as he tells us in the preface, was to introduce a method which, as he has found in his own teaching, has a "tendency to obviate thoughtless and mechanical work on the part of the student." The volume is divided into three parts. Part I comprises the Analytical Course, Part II the Theory and Part III the Descriptive Part; to which are added as appendices a list of apparatus and two sets of chemical labels. The object of the analytical course "is to introduce the subject of qualitative analysis in such a way as to develop the powers of observation, inductive reasoning and memory and at the same time to give a knowledge of chemical facts and methods which will be of use in the further study of this and related subjects." In general the methods of Fresenius are followed though with some changes. In the second part the student's knowledge of theory is supplemented by additional matter directly connected with analysis, the chapter on ions and ionization being especially valuable. In the third or descriptive part, the radicals are classified alphabetically, the properties upon which their analytical reactions are based being briefly given. The novelty as well as the excellence of the method developed in the Analytical Course seems of itself to justify the addition of this book to our analytical manuals. As a laboratory handbook it will prove most useful; being much smaller than the treatise of Fresenius, which must always remain the standard of reference. G. F. B.

2. *A Short Course in Inorganic Qualitative Analysis for Engineering Students;* by J. S. C. Wells, Ph.D. 12mo, pp. viii, 294. New York, 1898 (John Wiley & Sons).—This volume contains a short analytical course intended for the use of students who have only a limited time to devote to the subject. In the first section the grouping of the metals is considered, with the reactions of the several groups. In the second, the grouping and reactions of the acids are similarly treated. The third section is devoted to the analysis of actual compounds, especially of commercial products. The book is copiously supplied with "tables of scheme reactions," following the tables of group separations and those of separations of members of the groups. G. F. B.

3. *Introduction to Electro-chemical Experiments;* by Dr. Felix Oettel. Translated (with the author's sanction) by Edgar F. Smith. 12mo, pp. 144. Philadelphia, 1897. (P. Blakiston, Son & Co.)

Practical Exercises in Electrochemistry; by Dr. Felix Oettel. Translated (with the author's sanction) by Edgar F.

Smith. 12mo, pp. 92. Philadelphia, 1897. (P. Blakiston, Son & Co.)

The extensive introduction of electrical methods into chemical processes has given rise to the necessity of making electrochemical principles a part of higher education. In these little books Dr. Oettel has given in a complete form an outline of these principles and has thus done a service in this direction. The first volume is devoted rather to practical chemical electro-technics and the second to research methods. Dr. Smith's translation is an excellent one, as was to be expected from his well known position as an authority in this branch of chemical science. The books will do a good service in instruction. G. F. B.

4. *Remarks on Colloidal Glass;* by C. Barus. (Communicated.)—Following the suggestions in my earlier experiments, given in this Journal (3), vol. xli, p. 110, 1891, I have since been enabled to impregnate glass with water to such an extent as to make it fusible below 200° C. The solution occurs with contraction of bulk relatively to the ingredients and increasing compressibility, substantially as already stated, (l. c.) Heated in a gas burner in air, the new clear glass melts, swells up enormously with loss of water to a white porous pumice resembling pith. Long boiling in water turns it white superficially.

I am now able to announce the following results: Glass as a colloid is miscible in all proportions with water.

If these solutions are sufficiently concentrated, they coagulate at ordinary temperature and the congealed aqueous glass is not different in general appearance from common glass. The melting point of the coagulated aqueous silicate frequently lies below 200° C., probably above 150° C., depending on the glass.

Brown University, Providence, R. I.

II. Geology and Mineralogy.

1. *Late Formations and Great Changes of Level in Jamaica;* by J. W. Spencer. Abstract prepared by the author of a paper in the Transactions of the Canadian Institute, vol. v, pp. 324–357, 1898.—This paper is descriptive of the physical features of Jamaica which bear upon the evidence of great changes of level in late geological times, and extends the conclusions set forth in the author's work upon the "Reconstruction of the Antillean Continent."*

Speaking in a broad way, Jamaica is a dissected tableland, surmounting another but submarine plateau, extending from Haiti to the Yucatan banks, now submerged to depths of 3,000–4,000 feet. These banks have the form of old base-planes of erosion, but they are traversed by deep valleys more than 2,000 feet below the summit of the platform. Even within the limit of the submarine plateau mass, the channels reach to a depth of 9,600 feet, or more than 5,000 feet below the surface of the drowned plains.

* Bull. Geol. Sci. Am., vol. vii, pp. 103–140, 1894.

Here as everywhere, when studied, the valleys have in all respects the features of those of the plateau regions of Mexico and other countries. And they head in embayments of the land, receiving as tributaries the principal rivers of the district.

The modern topographic features of Jamaica date back, practically, only to the middle Miocene period; for the larger part of the island is covered by old Miocene white limestones. But the subsequent denudation has been enormous, for although the formation still reaches a thickness of 2,000 feet in some places, yet in others the dissection of it has penetrated the whole mass. Upon this old Miocene surface no Mio-Pliocene formations occur until those at the close of the period, showing it to have been one of long-continued elevation.

Upon these white limestones there was a subsequent mechanical deposit of marls, with pebbles (made up in part of older fragments), and in other localities there were gravels and loams (according to the source of the materials). These accumulations rise to a height of 500 feet in stratified beds, still nearly horizontal in contrast to the upturned beds of the underlying white limestone. They contain a few shells of modern species. The formations have been found to correspond, in position, with the Lafayette of the continent, or the Matanzas of Cuba, which have been provisionally placed at the close of the Pliocene period.

Overlying the Layton formation, where this has not been removed, and other formations found near the surface of the country, a mantle of stratified loams and gravels has been laid down. This occurs up to an elevation of 600 feet. It has been named the Liguanea formation, and has been correlated with the Columbia of the continent and the Zapata of Cuba. While no fossils have been found in this fragmental deposit, yet its stratified beds, occurring adjacent to the coast high above the sea, indicate its origin at sea-level. Thus it appears that the island was submerged to 500 or 600 feet during two distinct epochs, since the Mio-Pliocene period.

The paper describes the broad undulating features characterizing the Mio-Pliocene period. These have since been dissected by great deep valleys, extending from the land to the submerged plateau, formed subsequent to the Layton epoch; and from the depths to which they reach in the submerged plateau, the inference drawn is that the land stood 10,000 feet, or more, higher in the early Pleistocene period than to-day. The Layton formation, during this elevation, was enormously degraded, so that in many localities only remnants are found in protected places. Jamaica affords a favorable region for studying the contrast between the undulating topography developed near base-level of erosion during the Mio-Pliocene period of more extensive lands than to-day, and the great and enormously deep valleys of the post-Layton or early Pleistocene epoch. The molding of the submarine plateau is supposed to have occurred during the Mio-Pliocene period, while the deeply-drowned valleys are continuations of those of the land, which are of post-Layton age.

In contrast with these two features of erosion, that of the post-Liguanea epoch of submergence has been of small proportions; indeed, the post-Liguanea elevation is so recent that it has not passed beyond the stage of making narrow deep cañons. On account of this formation overlying the remains of the Layton series the different features of erosion, up to an altitude of 600 feet, are geologically preserved, while at greater altitudes they are not so easily distinguishable from those produced before the Liguanea epoch; yet when one has become familiar with the features of erosion, the respective epochs are generally recognizable. The post-Liguanea cañon-making epoch was characterized by an elevation of 150–200 feet more than at present; for the continuations of the existing rivers are traceable to that depth across the submerged coastal plains. The subsidence which caused the drowning of these valleys reached to an elevation of 10–25 feet below the present level; since which time the coral reefs of the coast have emerged to this amount.

Numerous as these oscillations appear, all of them, since the post-Layton elevations have been of comparatively small and diminishing proportions. These changes of level of land and sea have occurred on the other West India islands and on the continent; and from the amount of work accomplished, the Pleistocene period seems to have been one of long duration.

Outside of Jamaica, the geological features of that beautiful island would not be of special interest, except that here we find additional evidence, both upon land and the adjacent sea, supporting the theory of the high continental conditions of the West Indian region in the early Pleistocene period, when the land stood more than two miles above the present altitude, uniting North and South America, as is set forth in the "Reconstruction of the Antillean Continent."

2. *Resemblance between the Declivities of High Plateaus and those of Submarine Antillean Valleys;* by J. W. SPENCER. Tranactions of the Canadian Institute, vol. v, pp. 359–368, 1898.—This paper is a sequel to the "Reconstruction of the Antillean Continent,"* as in it the analysis of the slopes of the drowned valleys had not been considered. Both in the land and in the submarine valleys, their gradients are of two kinds: Those of rivers which are flowing over continental plains or upon the surface of high tablelands, where the declivities of the streams are so gentle as to be often reduced to even a foot per mile; (2) where the valleys are descending from higher to lower plateaus, in which case the descent is over a series of precipitous steps, separated by short gradation planes, marking pauses in the elevation of the land. Thus, if the mean descent of such a valley be taken, an average gradient would be entirely misleading. While the mean slope may reach from 100 to 200 feet per mile, it is found that in reality it is composed of perhaps twenty abrupt steps, with almost level flats between. Or the steps may reach a

* Bull. Geol. Soc. Am., vol. vii, pp. 103–140, 1894.

height of five hundred feet or more. Such features are seen descending from the Mexican plateaus (of 8,000 feet in altitude) to the Gulf of Mexico. The valleys end abruptly in amphitheaters indenting the floors of the tablelands and dissecting them.

In the drowned Antillean valleys, long reaches have been discovered with slopes of only a foot per mile, like that of the Mississippi, or of some plateau valley. These are separated by abrupt steps, similar to the succession of those descending from the margins of the Mexican tablelands. This point of analogy between drowned and land valleys, as well as the occurrence of short amphitheaters indenting the edges of the submarine plateaus, when carefully compared, very greatly strengthens the conclusions drawn in the "Reconstruction of the Antillean Continent"—namely that the valleys traversing the submarine Antillean plateaus were of land origin, and indicate the depth to which the West Indian continent has sunk, even to a depth of two miles or more.

3. *Die Eruptivgesteine des Kristianiagebietes*, Part III; *Das Ganggefolge des Laurdalits;* by W. C. BRÖGGER. (Videnskab. Skrift. I Math. Natur. Klasse, 1897, No. 6, Kristiania, 8°, pp. 376.)—The already classic work, which Prof. Brögger has been conducting for many years, upon the igneous rocks of southern Norway, is well known to all petrological geologists. The appearance of the present important volume, giving as it does the results of much careful observation and study both in the field and in the laboratory, will be greeted with the greatest interest and attention by all who are interested in the many problems connected with igneous rocks. The special phase of the region which is handled in this memoir is the nephelite-syenite and the attendant varied and peculiar dike rocks which accompany it. Of the many subjects which are discussed it is only possible in this brief notice to summarize the more important.

There is given first a full description of the nephelite-syenite, which receives the varietal name of *laurdalite.* This is characterized by an unusual amount of lime and magnesia. It is accompanied by masses of *pulaskite*, a rather acid type, low in alkalies and poor in nephelite, and by mica-syenite. All of these are regarded as differentiation products of the normal augite-syenite (laurvikite) of the region.

The accompanying dike rocks are divided into two main classes: (*a*) the dark colored, generally basaltic types, rich in ferro-magnesian components (lamprophyres) for which the author proposes the name of *melanocratic* rocks (μέλας, dark and κρατεῖν to rule); and (*b*) the light colored types of which the feldspars are as a rule the chief minerals and of which the aplites are a representative class; for these the name of *leucocratic* rocks (λευκός white) is suggested. (It appears to the reviewer that these terms would have had a greater use and precision if they had been constructed as nouns instead of adjectives, since the terms they are proposed to replace are nouns, i. e. direct names of objects.)

The *melanocratic* rocks described are *camptonites, kersantites, vogesites* and *monchiquites* of various types; together with *minettes*, rich in soda and containing aegirite, and *farrisite*. Farrisite is a new type, consisting of barkevikite, colorless pyroxene, a little lepidomelane and traces of olivine, iron ore, apatite, etc., mixed with a colorless tabular tetragonal mineral of the scapolite group which plays the part of the feldspathoid and makes up about 35 per cent of the rock. The structure is fine-granular and megascopically the rock is deep chocolate-brown in color and very compact. Another new type belonging to this class is *heumite*, a dark-colored, compact fine-granular rock composed of barkevikite and biotite with alkali feldspars as chief components and with smaller amounts of nephelite, sodalite and diopside.

The *leucocratic* rocks are *nephelite-porphyry, tinguaite, sölvsbergite, bostonite, foyaite* (Brögger uses this term to designate normal nephelite-syenites with trachytic structure while those with hypidiomorphic granular structure he terms "ditroites") and *hedrumite*. The last-named rock type is defined as the chemical and mineralogical hypabyssal equivalent of pulaskite, possessing trachytic structure and therefore composed chiefly of alkali feldspar and poor in nephelite. In addition syenitic aplites are described under this group of alkaline type—the *lestiwarites* of Rosenbusch. Of all these types chemical analyses are given and the mineral composition and systematic position are thoroughly treated.

In the concluding portion of the work the bearing of the facts observed on theoretical petrology is discussed and it is shown that these dike magmas are to be regarded as derived from the laurdalite magma by differentiation, the melanocratic and leucocratic types being complementary derivatives. Many questions of general interest are handled including a masterly discussion of the "kern" hypothesis of Rosenbusch which it is shown can be only accepted in a modified form. The latter portion of the memoir is indeed full of suggestions and will furnish material for thought to all petrologists. L. V. P.

4. *Baddeckite, a new variety of Muscovite;* by G. C. Hoffmann. (Communicated.)—This interesting variety of muscovite was met with about half a mile from the town of Baddeck, Victoria County, in the province of Nova Scotia, where it occurs, in the form of minute isolated scales, small scaly aggregations, and thin scaly layers, distributed through a highly plastic clay; which also contains a large proportion of fine crystalline, white, pearly scales of kaolinite, some minute crystals of white quartz and small particles of pyrite and calcite.

The mineral has a fine copper-red color, a pearly luster, and affords a tile-red streak. With water it forms a highly plastic mass. Its specific gravity, at 15·5° C., is 3·252. Before the blow-pipe it fuses, at about 4·5, to a shiny black slag, which on continued heating in the reducing flame becomes magnetic. It

is decomposed by strong hydrochloric acid, with separation of slimy silica. An analysis by Mr. R. A. A. Johnston, upon very carefully prepared and apparently perfectly pure material, showed it to have the following composition :—

Silica	48·96
Alumina	13·85
Ferric oxide	25·82
Lime	1·17
Magnesia	2·65
Potash	3-47
Soda	0·22
Water (direct estimation)	3·78
	99·92

These figures afford a ratio for $RO : R_2O_3 : SiO_2 : H_2O$ closely corresponding to $1 : 3 : 8 : 2$ giving the formula $H_4(Ca,Mg,K_2, Na_2)(Fe_2Al_2)_3Si_8O_{28}$, and assuming the hydrogen to be basic, the quantivalent ratio for $R' : R'' : Si$ of $3 : 9 : 16$ or for bases to silicon of $3 : 4$ agreeing with that required for some varieties of muscovite. The mineral is therefore a hydro-muscovite in which a very large proportion of the alumina ordinarily present is replaced by ferric oxide, and to this may be ascribed its exceptional behavior before the blow-pipe; its comportment with strong acids; as likewise its noticeably high specific gravity.

The name *Baddeckite* is given by the writer to this mineral from the above mentioned locality where it was first found.

5. *A Text Book of Mineralogy with an extended Treatise on Crystallography and Physical Mineralogy;* by EDWARD S. DANA. 593 pp. 8vo, with a colored plate. New York, 1898 (John Wiley & Sons).—A new edition of this work is announced as nearly ready; the following are quotations from the Preface:

"The remarkable advance in the science of Mineralogy, during the years that have elapsed since this text-book was first issued in 1877, has made it necessary, in the preparation of a new edition, to rewrite the whole as well as to add much new matter and many new illustrations.

The work being designed chiefly to meet the wants of class or private instruction, this object has at once determined the choice of topics discussed, the order and fullness of treatment and the method of presentation.

In the chapter on Crystallography, the different types of crystal forms are described under the now accepted thirty-two groups classed according to their symmetry. The names given to these groups are based, so far as possible, upon the characteristic form of each, and are intended also to suggest the terms formerly applied in accordance with the principles of hemihedrism. The order adopted is that which alone seems suited to the demands of the elementary student, the special and mathematically simple groups of the isometric system being described first. Especial

prominence is given to the 'normal group' under the successive systems, that is, to the group which is relatively of most common occurrence and which shows the highest degree of symmetry. The methods of Miller are followed as regards the indices of the different forms and the mathematical calculations.

In the chapters on Physical and Chemical Mineralogy, the plan of the former edition is retained of presenting somewhat fully the elementary principles of the science upon which the mineral characters depend; this is particularly true in the department of optics. The effort has been made to give the student the means of becoming practically familiar with all the modern methods of investigation now commonly applied. Especial attention is, therefore, given to the optical properties of crystals as revealed by the microscope. Further, frequent references are introduced to important papers on the different subjects discussed, in order to direct the student's attention to the original literature.

The descriptive part of the volume is essentially an abridgment of the sixth edition of Dana's System of Mineralogy, prepared by the author (1892). To this work (and future Appendices) the student is, therefore, referred for fuller descriptions of the crystallographic and optical properties of species, for analyses, lists of localities, etc., also for the authorities for data here quoted. In certain directions, however, the work has been expanded when the interests of the student have seemed to demand it; for example, in the statement of the characters of the various isomorphous groups.

6. *L'or dans la Nature;* by E. CUMENGE and F. ROBELLAZ. Premier Fascicule, 106 pp., Paris, 1898. (P. Vicq-Dunod et Cie, Éditeurs.)—This is a work of quite unusual character, in that it presents the subject of the occurrence of gold in nature in complete form from the various mineralogical, chemical, and geological standpoints. We have first a description of the crystallization of gold, then a summary of the composition of that from the different localities, and a general description of the occurrence of associated minerals. Following this is a brief chapter on the various minerals containing gold in nature and then an excellent digest of the gold regions in the different parts of the world. It is stated that the next *fascicule* will take up the subject of the distribution of gold in the geological formations, ancient and modern, auriferous gravels, and auriferous conglomerates, with a special study of the Transvaal. The work as thus far published can be highly commended, and in its complete form will doubtless prove of much value.

A series of thirteen excellent plates, which represent natural specimens of exceptional beauty of crystallization and interest of form, deserves very high praise.

III. Botany.

1. *The Illustrated Flora of the Northern States and Canada.** —When it was announced a few years ago that we were soon to have an illustrated flora of northeastern America, and that the preparation of this novel work was to be in the hands of Professor N. L. Britton, American botanists received the news with great interest. It was generally understood that on a number of fundamental points, such as the selection of both generic and specific names of plants and the conception of specific limits, the author of this proposed work was at variance with the usage of the distinguished botanist whose manual was then the only existing standard work covering northeastern America. It was, of course, assumed that in this new book those principles and conceptions would be worked out, and consequently, as the three volumes of the Illustrated Flora have appeared from time to time, they have been received with an interest doubtless greater than that which they would otherwise have aroused. Besides the desire to see the treatment of certain groups by Professor Britton and his associates, there has been a further anticipation of each volume on account of the illustrations—a unique feature in an American work of this scope. Altogether, then, this book must be regarded as one of the most important recent contributions to the literature of systematic botany.

The Illustrated Flora, as stated, has been prepared by Professor Britton, with the aid of a number of specialists and draughtsmen; and in the execution of the work the author has had the helpful coöperation of Judge Addison Brown. As we glance over the volumes, we are impressed with the neatness of their general appearance. The cuts, generally three on a page, are symmetrically arranged, dividing the space with the equally symmetrical descriptive text; and the accepted names, synonyms, descriptions, etc., have each their distinctive type.

In the adoption of the so-called Engler and Prantl system of arrangement, though as stated it is accepted with slight variations, the authors are to be congratulated, as that system, better than any other yet devised, gives us a near approximation to a natural arrangement of all plants. In capitalization, too, the book is certainly to be highly commended, for it adheres to good English usage, capitalizing the initial letters of all substantive specific names and all of personal or distinctly geographical origin. In fact, the work may be considered ultra-conservative on this point, adhering to the capital initial for geographical adjectives, a usage which many botanists, more conservative on the whole than the present authors, are tending to abandon. Another point which it is gratifying to see emphasized is the pronuncia-

* An Illustrated Flora of the Northern United States, Canada and the British Possessions; by Nathaniel Lord Britton, Ph.D. and Hon. Addison Brown. In three volumes. New York. 1896–98. (Charles Scribner's Sons.)

tion of personal specific names. In the Introduction it is recommended that such names be pronounced as nearly as possible as the men referred to would have pronounced them. In this way not only is a great deal of historic interest maintained, but there is the avoidance of many practically impossible Latin syllables.

The names adopted in this work are, as was expected, largely those of the so-called Botanical Club Check List, though in a number of cases other names, for some reason, have been substituted. This is not the place to discuss the nomenclature question—it would become too extensive a subject were one to take up its various phases. A recent paper* has shown very conclusively that the principles upon which the Check List is based are inconsistent, and consequently we can but regret that such names as will be only short-lived and which add confusion to the tangle of synonymy have been used in this work.

The English names, too, have received a great deal of attention, but unfortunately the authors seem to have lost sight of their true value and place. To many people it seems that if English names are to be given for the plants, they should be such as are actually used in colloquial speech by people who do not use the scientific appellations. Non-botanical people know only a comparatively limited number of plants—the commonest or most conspicuous or useful species—and for those they have their own names, sometimes imported from Europe, sometimes suggested by some characteristic of the plant, or often apparently a mere random name which has become fixed. Such names for a few species are numerous and often very different, and it is no simple matter to determine which are in most general use, but it is only such which should be used as colloquial names for plants. In a number of cases these standard names for showy plants are given, but in case of groups too inconspicuous or too difficult of separation for non-botanical folk to notice, the authors have manufactured a series of very uncolloquial designations—generally translations of the Latin names. Much time and thought must have been expended to accomplish what seems, unfortunately, a thankless task. Who that cannot say *Scleria reticularis* will ever say "Reticulated Nut-rush," or if he cannot say *Aster multiformis* will he be likely to speak of the "Various-leaved Aster"?

It is indeed a surprise in a work so ready to take up modern ideas to find the metric system of measurements quite ignored in the first volume. In the second volume, however, published after a number of adverse criticisms, the metric equivalents of the English units are given in a note, but the measurements are all given in the old standard feet, inches and lines.

It is not in these somewhat superficial matters alone, however, that a manual of systematic botany should be judged. Its worth as a working guide can be told only by use and by an examination of the descriptions, keys, ranges, specific limits, and, in this case, the illustrations. Reference has already been made to the neat-

*B. L. Robinson, Bot. Gaz., xxv, 437.

ness of the pages due in part to the studied symmetry of the descriptions; but this is secured at a very dear price, for through the carefully estimated symmetry of the text the most important point in scientific description, namely clearness, is lost. Most plants have not been over-described in the space allotted each species, but many trivial varieties (or, as generally treated here, species), which differ from the typical plants only in one or two details, could best be distinguished from those species by a mere phrase; while here that critical phrase is lost to the eye in a maze of unimportant details. For example, take *Houstonia ciliolata* and *longifolia* on page 214 of the third volume. These forms differ from each other only in minor and inconstant characters, yet an examination of the text will show that many general points in one description are repeated in the other, quite obscuring the essential differences which should be brought out. Again if the essential features of each species were in some way emphasized or contrasted with the distinguishing points of related species, much would be gained toward the clearness and ready usefulness of the work. In the Appendix this seems to be realized; but it would vastly increase the real value of the book as a field or herbarium companion if this method had been adopted before the last few pages of the third volume.

Intimately associated with the descriptions are the figures. These, as a whole are very attractive; but here, as in the descriptions, the test should not be the mere superficial appearance, but the presentation or omission of specific characters and the accuracy of details. From a general examination it would seem that in groups where the specific characters are largely habital the figures will prove of considerable service. In such groups, unfortunately, as require accuracy of detail and the representation of special parts, the figures are often most disappointing. A few groups should be made exceptions to this statement; for instance, in the *Naiadaceæ*, in which the text is by the late Doctor Morong and the figures are mainly reduced from the larger ones of his monograph, the details are very well brought out. In some groups, on the other hand, there seems not a little carelessness in either the drawings or the descriptions; at any rate, they are decidedly at variance. In the genus *Carex*, for example, it is surprising to find accompanying the description of *C. crinita* and the figure of a *crinita* perigynium a good habital sketch of *C. gynandra*. *Carex Raeana* is a slightly different case. Professor Britton reduces to *C. Raeana* *C. miliaris* var. (?) *aurea*, Bailey, a very different form; and he has figured as *C. Raeana* the latter plant. A comparison with Doctor Boott's plate of *C. Raeana* shows the Illustrated Flora figure to have striking differences. The leaves of *Salix Barclayi* are described as serrulate, yet in the figure the plant is represented with entire leaves. *Senecio sylvaticus* is distinguished from *S. vulgaris* principally by the simple involucre, lacking an outer short series; but the figure shows an involucre with the outer series of *S. vulgaris*. Other

careless drawings have been noted, but these cases are sufficient to show the caution which must be exercised in referring to the illustrations.

Another unfortunate feature of the drawings, not so much due to carelessness, is the omission of important details which must be relied upon, in many cases, for determination; or often the drawing of details in one case and their omission in contrasting cases. In Aster, for instance, very important characters are found in the involucre, yet hardly an involucre in the whole genus is drawn with sufficient accuracy of detail to be of much help. On the other hand, enlarged drawings are made in many cases of both ray and disk flowers, quite useless details without any readily accessible characters; and sometimes there is a drawing of a single involucral bract with no intimation whether it came from the outer, inner, or intermediate series.

In one group of *Aster* in particular, the section *Biotia* including the well-known *A. macrophyllus* and *A. corymbosus*, it was important that the illustrations, if any, should be perfectly accurate; for in treating this group alone Professor E. S. Burgess has described no fewer than ten new species and fourteen new varieties, besides reviving three old species. In view of the extended and most painstaking study which he has given this group, it was hoped that the presentation of his conclusions would make quite clear the diverse forms which constitute it. In this matter, however, we must confess great disappointment: from the descriptions alone, it is difficult to feel certain which of the new forms one has in hand. There are doubtless quite recognizable differences in the plants; but when the successful use of the key depends upon one's interpretation of the exact shade of difference between "predominant glands large, capitate" and "predominant glands minute, scarcely capitate," the student cannot help wishing for good enlarged figures of the glands. In two cases there are drawings presumably intended to show the glands, but, as no scale of measurement is given, it is impossible to compare even those with satisfaction. In attempting to make out these forms the student might make fair progress, after all, were he not hampered by the discrepancies between the descriptions and figures and even between the figures themselves. The second species of the group, *Aster tenebrosus*, is described as having "leaves very thin and smooth"; yet in the figure the leaves are represented as hairy as those of *A. Schreberi*, with "leaves . . . rough above, with scattered slender appressed bristles." The basal leaves of *A. curvescens* are said to have "a broad shallow sinus," and those of *A. nobilis* have "the sinus deep, broad, or the lobes overlapping"; yet in the figures it is difficult to detect a shade of difference in the sinuses. The basal leaves of *A. roscidus* are described with "the sinus deep," and the stem leaves are "chiefly orbicular and not cordate, with short broadly winged petioles, rarely slender-petioled"; but in spite of the description the accompanying figure shows an elliptic-ovate basal

leaf tapering gradually to the petiole, and similar but smaller sessile stem leaves. With such inconsistencies as these between descriptions and figures it is of course impossible to form any just opinion as to the validity of the species which are here described.

Throughout the work, as was expected, the tendency seems to be to regard as species many forms which have often been regarded merely as varieties. In many cases this course seems the proper one in view of recent studies and increased data. For instance, the separation of some forms from *Pyrola rotundifolia* seems quite proper: *P. asarifolia*, at any rate, is a plant with very different foliage and range, and its rose-colored flowers are expanded some weeks before those of the more southern white *P. rotundifolia*. *Amelanchier rotundifolia*, a species of northern river-banks, blooms in late May and in June, and matures its fruit in late August or September, long after that of *A. Canadensis* has fallen. It is a pleasure to see this plant put on the same basis as *A. Canadensis* and *A. oligocarpa;* but it is not quite clear how the Rochester Code allows the specific name *rotundifolia*, first applied as a varietal name to this plant in 1803, when there is already the European *A. rotundifolia*, Decaisne, founded upon *Cratægus rotundifolia*, Lam. Encyc., i, 84 (1783).

On the other hand, many of the old varieties, here raised to specific rank, seem to have less upon which to rest. The *Houstonias*, *H. ciliolata* and *H. longifolia*, already referred to, are well marked as extreme variations from *H. purpurea*, but with a large proportion of specimens falling between these different forms and showing many combinations of their characters, it is hard to see how they can be counted as of specific rank. In treating *Salsola*, Professor Britton keeps apart as species *S. Kali* and *S. Tragus*. How, after the observations of M. Constantin,* these plants can be regarded as more than forms of the same species, is not easy to understand. According to M. Constantin, when the seashore *Salsola Kali*, with coriaceous calyx and fleshy leaves, creeps up the rivers, the calyx becomes membranous and the leaves less fleshy, thus passing directly into the so-called *S. Tragus*. Contrasted with the treatment of *Salsola* the case of one of the common aquatics, *Myriophyllum humile* (*M. ambiguum*) may be taken. One form of the plant is very small with short leaves, and it grows in shores (*M. ambiguum*, var. *limosum*, Torr.). Another form, appearing very different, becomes even two feet long, has fine elongate-capillary leaves and grows in water (*M. ambiguum*, var. *capillaceum*, Torr. and Gray.) Yet Professor Britton (in this as in his general treatment of the group, closely following the late Doctor Morong) gives no recognition to these extreme forms, considering them "only conditions of the plant dependent upon its environment." What but environment, we may ask, has produced the peculiarities of *Salsola Tragus?*

* Jour. de Bot., 1887, 44.

In spite of the general tendency toward the elevation of minor forms to specific rank, there are a few noteworthy cases where well recognized forms have been reduced to other species. *Rosa lucida*, a species which with *R. humilis* has given eastern botanists more difficulty than almost any other common plant, is well treated, as formerly proposed by Mr. Best, as a variety of the latter species. In some other cases the reductions are less happily made. The case of *Carex miliaris*, var. (?) *aurea* has been cited. The related *C. miliaris*, var. *major*, Bailey, is unwisely reduced, it seems to us, to *C. miliaris*, Michx. The plants are in reality quite as different from one another as *Carex filiformis* and its variety *latifolia*, treated by Professor Britton as a distinct species, *C. lanuginosa*, Michx.

In discussing the specific limits and the figures in certain groups, mention has been made of the keys to species. These, of course, can be tested only by continuous use. Already the course of regular work has given an opportunity to try them in certain groups where carefully planned keys are important. In the genus *Aster* the key is based primarily upon the most obvious character of the plant,—the leaf—and, so far as it has been tested, with the exception of the group just discussed, it proves to be very helpful. In *Salix*, on the contrary, the key promises to be of little use, even to one somewhat familiar with the group. This is due to the illogical divisions, some of the primary groups being based exclusively on the staminate flowers, and their secondary divisions on the capsules.

The points already discussed, with the exception of accuracy of descriptions and figures, are matters to be decided in part by individual judgment; but there is one other essential to the good treatment of a flora, the geographical range of each species, in which absolute facts alone can be consulted. In determining the range of a given species it is possible to get an incomplete view by consulting a single large herbarium. A broader view may be gained by consulting a number of herbaria receiving large collections from different sources, and a still broader view is possible by consulting the more accurately prepared local floras. The most satisfactory results possible are gained by a combination of these methods, and it is asking none too much of our monographers to take advantage of all such opportunities as are open to them. Yet in the statement of geographic ranges the Illustrated Flora is exceedingly disappointing. The New England States, for example, have given issue to many lists and local floras, a number of them works of great accuracy, and the specimens upon which these publications are based are deposited in public herbaria or in private collections accessible upon request to critical students of systematic or geographic botany. In view of these standard publications and readily accessible herbaria, it is a surprise to find that in the statement of ranges of scores and scores of well known New England plants, their occurrence in the local lists is quite ignored.

Stellaria borealis (*Alsine borealis*, Britton) is one of the commonest plants in northern New England, extending northward to northern Labrador. The eastern range, as given in the Illustrated Flora, is "Rhode Island to northern New Jersey . . . . Ascends to 5000 ft. in New Hampshire."

Ranunculus multifidus is a common plant from central Maine southwestward throughout New England, yet the range given for that species (as *R. delphinifolius*) is "Ontario to Michigan, south to North Carolina and Missouri."

Nasturtium sylvestre (*Roripa sylvestris*, Bess.) grows near streams in Newfoundland and Maine (its occurrence in Maine reported in Bull. Torr. Bot. Club, xix, 340), but the range is stated "from Massachusetts to Virginia and Ohio."

Myriophyllum alterniflorum is a common plant in Maine waters and it extends to eastern Massachusetts. Its occurrence in Maine was published on the same page as the note on *M. Farwellii*, a species which Professor Britton has included from that State; yet in stating the range of *M. alterniflorum* no intimation is given that it grows in the United States.

Ligustrum vulgare is one of the commonest shrubs in rocky woods of eastern Massachusetts, recorded as a wild plant by Menasseh Cutler as early as 1785. The range here given is "Ontario and western New York to Pennsylvania and North Carolina."

Polygonum Careyi is locally abundant from northern Maine to Rhode Island, and its occurrence in Maine was given in Doctor Small's Monograph of the genus, and in his preliminary list (Bull. Torr. Bot. Club, xix, 353) Maine specimens are cited; yet now the same author gives the range "Ontario to Rhode Island, New Jersey and Pennsylvania."

But perhaps the strangest thing of all is to see our common *Lobelia spicata* entirely excluded from New England by the range "Ontario to the Northwest Territory, south to North Carolina," etc.

When we consider the multitude of species overlooked or ignored in a region so well represented by good local lists as is New England, it is easily seen what must be the experience of those who examine the Illustrated Flora with eyes familiar with plants of an area less thoroughly explored than that here taken as a standard.

In one other particular the Illustrated Flora is often disappointing. It aims to give in the synonymy of each species the recent current names of the plant. This is a good point and one which will be of great assistance to those who come face to face for the first time with the strange names here taken up; but if this detail could have been more carefully attended to, the usefulness of the book as a reference work would be enhanced. It is a disappointment in looking for some familiar name to find it absent, even as a synonym. One of our common elders has been known as *Sambucus racemosa*, but that name is not mentioned in the

treatment of the genus. An Arctic-alpine form of *Campanula rotundifolia* has been known to us as var. *Arctica*, yet that name is not given as a synonym of var. *Langsdorffiana*. A common *Luzula* in the White Mountains and northern Maine has been familiar as *L. spadicea*, var. *melanocarpa*, but under its more recent alias, *Juncoides parviflorum*, Coville, the more familiar synonym is not mentioned. In the so-called Botanical Club Check List the plant which we have known and which is now kept up as *Puccinellia maritima*, was called *Panicularia maritima ;* yet for some reason this name does not occur in the Illustrated Flora synonymy. One of the familiar White Mountain grasses has long passed as *Agrostis canina*, var. *alpina*, Oakes. In the Botanical Club Check List, Professor Scribner made a new combination, *Agrostis rubra*, L., var. *alpina*; but now in the Illustrated Flora the plant is called *Agrostis rubra*, and both the Check List name and the other are quite omitted from the synonymy.

In many particulars, then, the Illustrated Flora is hardly what we should like to see it. In most groups where the representation of minute details is important the figures can be used only with hesitation. The descriptions also, to one whose time is of value, are far from satisfactory. Printed in one style of type and often filled out with non-essential details, they are not readily interpreted. Unfortunately, too, the descriptions and the accompanying figures are often contradictory ; and in the statement of geographic ranges there has been so general an ignoring of well known and accessible data, that one can feel little confidence that the ranges of most species are given with even approximate accuracy.

On the other hand, there are fortunately some notable exceptions to the general run of figures. In the *Naiadaceæ*, *Alismaceæ*, *Gramineæ*, *Juncaceæ*, *Polygonaceæ*, and a few other families, most details are well brought out and the illustrations promise to be helpful. In the adoption of the Engler and Prantl system of arrangement too, the Illustrated Flora has taken a wise step; and in spite of its inaccuracies and inconsistencies, when one wishes to gain from the Illustrated Flora only a general impression of the plant, it is certainly a great convenience. As a work for such reference it will find a welcome place in many libraries.

M. L. FERNALD.

OBITUARY.

PROFESSOR JAMES HALL, State Geologist of New York from 1836 to 1898, died at Bethlehem, N. H., on August 7th, at the advanced age of eighty-seven years. A notice is deferred until another number.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXVII.—*The Compressibility of Colloids, with Applications to the Jelly Theory of the Æther;* by C. BARUS.

1. COLLOIDS in view of their varied and frequently anomalous physical properties,* not to mention their tremendous biological importance, offer a fascinating field of research. I have, however, undertaken the present experiments rather with ulterior motives, because of their bearing on the elastic properties† of glass, geologically considered. Apart from this, certain practical difficulties have presented themselves in the course of my work for which I hope the present paper will suggest a remedy. Thus, in endeavoring to ascertain the effect of pressure on solution,‡ I was invariably confronted by the difficulty that the solute precipitated by pressure collects at the bottom of the piezometer tube, is segregated from the bulk of the solvent and therefore no longer in place for solution on removal of pressure. Methods which work faultlessly for fusion are thus apt to fail when applied to solution. Now if it can be shown that the physical properties of a solution vary but slightly in presence of a colloid, that the former may be made viscous enough to retain the precipitate in place during compression, I see no reason why the fusion methods are not adapted for the study of solutions.

A final inquiry of great interest is the compressibility of well coagulated colloids, seeing that compression is apt to be accompanied by the breakdown of stress in a solid medium. Indeed I here encountered some astonishing phenomena, and a

* On analogies in the thermal behavior of india rubber jelly, muscular tissue, etc., see Bjerken, Wied. Ann., xliii, p. 817, 1891.
† See my paper in this Journal, xli, p. 110, 1891.
‡ Bulletin U. S. Weather Bureau, No. 12, p. 18 et seq., 1895.

large part of the present paper will be devoted to them. I say astonishing, as I have been able to force little mercury projectiles, often less than $\frac{1}{10}^{\mathrm{mm}}$ in diameter, though a solid wall of coagulated jelly over 15^{cm} thick, by the directed action of hydrostatic pressure applied on the outside of the wall. I know of no other case of well-defined persistent motion, performed by bodies in a highly viscous medium, and resulting from the breakdown of mechanical stress within it, wholly without the action of external forces "acting at a distance."

2. The earlier literature of the subject is meagre and I may refer regarding it to a paper by G. de Metz,* to whom some of the best data are due. He accentuates the variable character of the constants observed and certain changes (gelatine) in the lapse of time. Papers like those of Fraas,† Maurer,‡ and others quoted by the former, refer to the elastics and to the viscosity of colloids, in a way differing from that here considered.

I do not in the present paper aim at reaching more than an estimate as to how far the elastic properties of a solvent are modified, when it is made thoroughly viscous by the addition of a suitable quantity of colloid. I have therefore subjected the bodies to pressure in capillary tubes, a method which though it does not admit of the application of very high pressure, has the undeniable advantage of exhibiting the progress of the experiment to the eye throughout. I have already described the precaution necessary in a former paper§ in connection with an extensive survey of the compressibility of liquids, and need therefore only state here that the body to be examined is introduced into a well annealed capillary tube of fine bore between two terminal threads of mercury. One of these (the upper) is sealed in place; the lower is movable and transmits the applied pressure. The lower meniscus of the upper and the upper meniscus of the lower thread are observed by aid of a cathetometer, through a clear glass boiling tube, of the kind frequently described in my high temperature work.‖

3. It is sufficient for the present purposes to examine two classes of colloids, representing extremes of compressibility. In the first case of low compressibility water is to be the solvent and gelatine and albumen were selected. In the second case (high compressibility) ether is the preferable solvent and solutions of pure india rubber are thus available.

A solution of 10 per cent by weight of clear gelatine in water sets quite firmly at ordinary temperatures and is not too

* G. de Metz, Wied. Ann., xli, p. 663, 1890.
† Fraas, Wied. Ann., liii, p. 1074, 1894.
‡ Maurer, Wied. Ann., xxviii, p. 628, 1886.
§ This Journal, III, xxxix, p. 478, 1890.
‖ Cf. Bull. 54, p. 88, U. S. Geolog. Survey, 1889.

viscous at higher temperatures to admit of introduction into a fine capillary bore. Greater difficulty is experienced with the 20 per cent solution. Albumen is advantageously introduced in the natural state as white of egg.

Considerable trouble was encountered in charging the tube with india rubber, though a 5 per cent solution in ether was manageable. The presence of traces of sulphur is apt to foul the meniscus, while the absorption of water from air by condensation is unavoidable during filling.

The remarkable volume-elasticity of water makes it a difficult body to observe by the present method. Thus for a thread 10^{cm} long, the motion of the meniscus will scarcely exceed ½ millimeter per 100 atmospheres. For longer threads and higher pressure the case is proportionately favorable, but in no practical case is an accuracy of more than 3 or 4 per cent to be looked for, quite aside from the compressibility of the glass. The latter is best eliminated and sufficiently so for the present comparisons, by examining all the samples as far as possible in the same tube. For ether the case is 2 to 8 times more favorable, depending on temperature.

4. The following data, selected from a large number of similar experiments, will best exhibit the results obtained. In the tables θ denotes the temperature of the thread of total length L in cm., while l is the decrement of length for the pressure p (in atmospheres) stated. Hence l/L, the decrement of length per centimeter, is also the decrement of volume at the given temperature and pressure. The solvent and colloidal solution may be conveniently compared in two ways: one is to plot l/L varying with p for each substance; the other to compute the mean compressibility β within the same pressure interval (usually about 200 atm.).

TABLE 1.—Compressibility of water and colloidal solutions of gelatine and albumen in water.

Water.			Gelatine 10%.			Albumen (Natural).		
θ, L	p	l/L	θ, L	p	l/L	θ, L	p	l/L
23°	0	·0000	----	---	----	22°	0	·0000
$17·4^{cm}$	83	037	---	---	----	$12·3^{cm}$	81	039
	160	075	----	---	----		128	061
	226	108	----	---	----		191	093
100°	0	·0000	100°	0	·0000	----	---	----
$18·1^{cm}$	83	046	$21·1^{cm}$	116	058	----	---	----
	180	098	----	211	100	----	---	----
	244	133	----	282	133	----	---	----

Corresponding values of l/L and p are given for water, gelatine and albumen in aqueous solution in Table 1. At ordi-

nary temperatures water and albumen on graphic representation show nearly the same compressibility, so far as the present method goes; at 100° gelatine is throughout less compressible than water, the difference being as large as 10 per cent.

In Table 2 I have computed the compressibilities β for each of the three cases, at different temperatures θ. Observations were made in triplets, beginning and ending in the same low pressure at each temperature. This eliminates change of temperature due to cooling of the water bath. The colloids were kept liquid throughout; though the albumen turned white gradually at the higher temperatures, it did not at once set firmly.

TABLE 2.—Compressibility of water and of colloidal solutions of gelatine and albumen in water.

Water.			Gelatine 10%.			Albumen (Natural).		
θ, L	p	$\beta\times10^6$	θ, L	p	$\beta\times10^6$	θ, L	p	$\beta\times10^6$
23·3°	5	..	21·4°	5	..	22°	5	..
17·4cm	160	48	20·3cm	177	51	12·3cm	128	50
100°	10	..	23·6°	5	..	28·8°	4	..
18·1cm	198	52	20·3cm	165	50	12·3cm	181	50
			25·8°	12	..	27·5°	4	..
			20·3cm	190	52	12·3cm	178	47
			29·2°	12	..	49·5°	4	..
			20·4cm	188	53	12·4cm	192	52
			32·0°	18	..	53·5°	4	..
			20·4cm	187	52	12·4cm	176	50
			36·8°	30	..	57°	1	..
			20·4cm	201	49	12·5cm	190	50
			43·5°	30	..	59·6°	1	..
			20·5cm	186	50	12·5cm	203	48
			53·3°	31	..	*63·6°	2	..
			20·6cm	181	52	12·5cm	187	55
			100°	10	..	*67·5°	11	..
			21·1cm	185	51	12·5cm	195	52
			100°	12	..			
			21·1cm	197	51			

The results are not unlike the preceding set. The compressibility throughout remains very nearly that of water.

* Coagulating but not set. Threads break off, observation difficult.

Neither for gelatine nor for albumen is an increase of compressibility with temperature certainly indicated, whereas this is definitely the case with water.

It is difficult to state whether these detailed results are real. I will pass it over, mentioning merely that it is always a delicate question to decide whether the heat generated on compression has all been dissipated. In a cooling water bath, moreover, the residual effects of thermal expansion are apt to be superposed as the compression results. Finally in case of coagulated albumen, threads break off and are lost in the opaque body.

The endeavor was now made to prepare as concentrated a solution as could be filled into the fine capillary bore. The ingredients were weighed out for a 20 per cent solution, though the concentration may have been less. It coagulated firmly, showing marked elasticity in threads.

Measurements were first made for the coagulated thread as will be shown below, § 7 et seq. After this the tube was kept at 100° for some hours and examined from time to time. The earlier results contain no additional information and will be omitted. The final data are given in Table 3. Compressibility β refers to the total interval from $p=0$ to the value of p given.

TABLE 3.—Compressibility of a 20 per cent solution of gelatine in water.

θ, L	l/L	p	$\beta\times 10^6$
100°	·0003	7	--
17·01^{cm}	056	114	49
	103	216	48
	156	319	49
	185	381	49
	126	268	47
	082	171	48
	038	87	44
	003	8	--

These new data practically coincide with the former albumen and gelatine (10 per cent) values; if anything the former show greater compressibility. They coincide nearly with the compressibility of water at 23°, and fall definitely below the water compressibility for 100°. Little or no effect is therefore observed by the additional concentration of the new solutions.

5. Table 4 contains results similar to Table 1 for ether and an etherial solution of caoutchouc (not vulcanized). If the volume increment l/L be laid off in terms of the corresponding pressure p, it is found that the curves for the colloidal solution and the solvent ether coincide very nearly both at low temperature and at high temperature. Since in the former

case the colloid is at a lower temperature (24°) as compared with ether (29°), this would indicate greater compressibility for the india rubber solution. Even at 100° this state of things is not quite wiped out. These results thus recall the case of the preceding paragraph.

Here again, however, I do not wish to insist on these detailed observations, because of manifold sources of error incident to the method. The present results demonstrate all that I asked of them in showing that to ascertain the effect of the colloid on the compressibility of the solvent, it is necessary to use some much more sensitive method than the direct capillary tube comparisons of the present paper.

TABLE 4.—Compressibility of ether and of an etherial solution of caoutchouc, about 5 per cent by weight.

Ether.			Caoutchouc-ether solution.		
θ, L	p	l/L	θ, L	p	l/L
29°	20	·0000	23·9°	45	·005
$14·57^{cm}$	100	137	$7·72^{cm}$	123	17
at 20^{atm}	200	291	at 20^{atm}	195	27
	300	423		286	38
	400	540		---	---
100°	10	·0000	100°	57	·021
$16·85^{cm}$	100	·0357	$8·93^{cm}$	148	51
at 10^{atm}	200	·0653	at 10^{atm}	221	71
	300	·0876		298	88
	400	·1060		---	---

6. The last two paragraphs, therefore, show in a general way that the compressibility of a colloid is essentially determined by the solvent for a wide range of concentration and throughout enormous variations of viscosity, so long as the solution is liquid, however viscous it may be. In so far as compressibility is decreased, the decrement will not exceed the amount corresponding to the displacement produced by the mere bulk of colloid present.

The essential identity of behavior of a solvent in the presence or absence of dissolved colloid seems first to have been definitely expressed in 1888 by von Tiezen-Hennig,* reasoning from the results of electrolytic experiments.

In this place I may add a correlative result obtained in my experiments on the solution of vulcanized india rubber,† where it is shown that the melting point of the coagulated colloid is practically independent of the solvent contained.

* "Ueber scheinbar feste Electrolyte," quoted by Bjerkén, l. c.
† This Journal, III, xlii, p. 359, 1891.

7. As has been stated, these inferences refer specifically to liquid colloidal solutions. The interesting question now presents itself: In what respect does compressibility change when the liquid colloid thoroughly coagulates,* or changes in relation to viscosity from a viscous liquid to a soft solid.

The results for coagulated gelatine solutions are given in Table 5; but the datum β is here, at the lower temperature, merely a superior limit compressibility, for reasons which I shall presently explain. § 8. The true compressibility is probably less than $\frac{1}{8}\beta$; indeed no true compressibility may have been measured. As temperature rises (33°, 41°, 51°), approaching the melting point, the normal compressibility† of the solvent water is rapidly approached here, as was the case in Table 2 for albumen. Stress therefore breaks down the friable solid, triturates it as it were, the colloid being altogether too soft to resist the advancing column of mercury appreciably like a solid. Whenever a sufficient number of internal discontinuities is at hand (unstable configurations, virtually) the solid is proportionately liquid.

TABLE 5.—Coagulated colloids.

Gelatine 10 per cent.				Albumen* coagulated at 100°.	
θ, L	p	l/L	$\beta\times10^6$	θ, L	
22°	0	.000	—	22°	No motion of meniscus observed as far as 200^{atm}. At higher pressures threads of mercury pierce the core and make further measurement impossible.
$20{\cdot}2^{cm}$	97	1	10	$12{\cdot}7^{cm}$	
	210	2	10		
	0	0	—		
Another sample:					
24°	0	·0000	—		
$13{\cdot}2^{cm}$	105	23	26		
32·7°	0	·0000	—		
$13{\cdot}3^{cm}$	104	49	47		
40·8°	0	·0000	—		
$13{\cdot}3^{cm}$	92	38	41		
51°	0	·0000	—		
$13{\cdot}4^{cm}$	117	55	47		

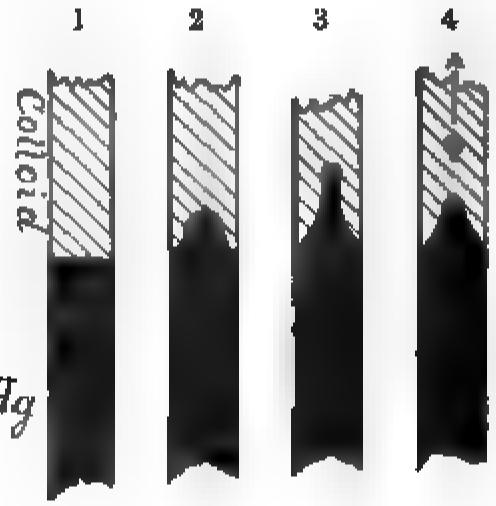
*Heated about 10 minutes, the white thread expands. Examined next day after setting. Meniscus fouled by sulphur corrosion.

8. The compression of the solid colloid is accompanied by characteristic phenomena (as has just been intimated), deserving special examination. They are shown in the annexed figures, where the contiguous threads of mercury (below) and colloid (above) meeting at the lower meniscus are alone represented, the walls of the capillary tube containing the threads being ignored.

* That time for setting is essential here has already been emphasized by de Metz, Fraas and others (l. c.), and in the above work with albumen.

† Cf. § 11, relative to suggestions of Carus-Wilson.

When pressure continually increases (very gradually), the meniscus in 1 passes into the conoidal form 2, thence into the unstable figure 3, from which presently a drop is shot off, upward. This exceedingly minute projectile may penetrate the whole column of coagulated colloid, 13^{cm} or even 20^{cm} long. The phenomenon repeats itself at consecutive intervals even at constant pressures.



FIGS. 1, 2, 3, 4. Deformations observed on compression of a coagulated colloidal thread, by a mercury meniscus advancing from below.

With the 10 per cent gelatine coagulum, on one occasion, I counted twelve of these little projectiles (on another thirteen, etc.), each less than $\frac{1}{10}$ mm. in diameter and disposed at regular intervals, i. e. nearly equidistant in the axis of the column of coagulated (solid) colloid. The top one rose 12^{cm} through the medium and against gravity, the lowest about 1^{cm} above the meniscus. On removing pressure five of them gradually dropped back upon the meniscus, which in the telescope soon resembled a bunch of silver grapes. When the tube is allowed to stand vertically over night with pressure removed, all drops often fall out of the colloidal column before morning. This motion of droplets, up or down, is equally evident to the naked eye.

At other times and particularly with older or abused columns, balloon-shaped projectiles even $\cdot 5^{mm}$ high break off and walk up leisurely through the colloid, say at a rate of $2^{cm/sec}$. The motion on close inspection is apt to be jerky. In such cases, a trail of exceedingly small droplets, scarcely $\cdot 02^{mm}$ in diameter, is apt to be seen in the axis of the tube, where there was no such trail before, or even in advance of the large drop.

The phenomenon is best seen after slow cooling of the thread. On change of pressure slow creeping of drops across the crosshairs of the telescope is a frequent occurrence. Irregular dispositions of the drops were also often observed.

To further elucidate these phenomena additional experi-

ments were made with the 20% gelatine solution, after thorough coagulation. In two experiments I was fortunate in breaking off very short mercury threads while the colloid was still liquid, to indicate the nature of the strain above the meniscus. In one case this drop, originally ellipsoidal in form, sharpened upward as pressure increased, until at about 150 atm. the conoid completely *exploded*, giving rise to about fifteen small projectiles distributed along the lower 10^{cm} of the column of coagulated colloid. The motion, which is extremely swift at first, of the order of several meters per second, as I judge, dies down gradually within 5 to 10 minutes to the merest creeping.

A full protocol of a similar experiment on a continuous column, thoroughly coagulated after slow cooling from 100°, is given in Table 6. A drop of mercury originally nearly round in appearance was here also present just above the meniscus. As pressure increased, accompanied by the sharpening apex of the conoidal meniscus already described, the base of the drop in all cases remained apparently convex, while its sides sloped even more steeply than the meniscus of the column of mercury. It may have been reëntrant and the cone hollow, but I did not notice this.

TABLE 6.—Compression of a coagulated 20 per cent gelatine solution.

θ °C	L cm	p atm	Remarks.
24°	16·325	16	*
	16·310	92	(1)
	....	115	(2)
	16·310	130	(3)
	16·305	160	(4)
	....	170	(5)
	16·310	200	(6)
	16·300	265	(7)
	....	300	(8) Tube breaks.

* The tube originally showed a good meniscus (obtained by slow cooling from 100°) and a detached, apparently round *drop* of mercury a few millimeters above it.

(1) Both meniscus and drop sharpen conoidally, with the apices directed upward.

(2) Further sharpening. The drop shoots off one little projectile, tadpole-shaped, $\cdot015^{cm}$ long, which penetrates upward *alone*, very fast at first, slowing up gradually to zero. The motion continues visibly several minutes. Another projectile follows in the same way. Both eventually stop about 4^{cm} above the meniscus and $\cdot5^{cm}$ apart.

(3) Two more projectiles shot off consecutively from the drop. The two former rise but slightly; the latter come to rest below them.

(4) The top (original) projectile now rises, tadpole fashion, to 8^{cm} above the meniscus. The others gradually meet and coalesce, rise without meeting the first. Meantime new projectiles have been shot off by the drop, which successively rise, forming a close group 4^{cm} high. Simultaneously the very sharp meniscus of the lower mercury column has been firing projectiles through the

9. At first sight these phenomena seem to be of a capillary nature. Drops of oil break off in Plateau's well known experiments more slowly but otherwise in much the same way. The tendency to jerky motion and much else suggests the action of surface tension.

A moment's reflection shows, however, that surface tension cannot be the primary motive force,* since droplets of mercury often less than ·01^{cm} in diameter are to be projected through a coagulated (solid) colloid, a distance of 10^{cm} or more. Again these projectiles often start afresh in their motion (cf. Table 6), when many centimeters above the meniscus. In these fine bore tubes (diameter ·031^{cm}) capillarity necessarily plays an important part; but it is of entirely subordinate interest and I shall not further mention it.

The real phenomena is elastic in character. The original meniscus in figure 1 loaded with a uniform pressure upward from below, is deformed in accordance with a shear symmetrically around the axis of the tube. The colloidal meniscus yields very much as any elastic disc secured at the edges and uniformly loaded would do. It is strongest at the edges, which are sustained by the glass walls of the capillary throughout the length of the colloidal column, and weakest at its axial points. As pressure increases the strain gradually reaches the limit of

narrow dissepiment of colloid *into the drop*, replenishing it in substance but giving it the appearance of a grape cluster with apex upward.

(5) Further projectiles shoot off from the drop. They induce the 4^{cm} group to penetrate farther upward. The top group is stationary.

(6) Meniscus shooting into the drop at its base: the drop discharging many projectiles from its apex. They induce motion in the preceding group (without reaching them), which in their turn actuate the earlier group until finally the upper (original) group moves nearly to the top of the column. Various projectiles have coalesced. Distribution of projectiles from the meniscus upward is now as follows:

Meniscus	·00^{cm}	Projectile	5·73^{cm}	Projectile	13·41^{cm}
"Drop," clustered	·21	"	6·93	"	14·38
Projectile	·38	"	7·91	"	14·56
"	·51	"	8·13	Original Projectile	14·62
"	3·29	"	8·52		
"	3.33	"	10·13	Top meniscus	16·13
"	3·73	"	11·32		
"	3 90	"	12·40		

(7) Further projectiles shot off from drop, which is now smaller but *still in place.* Top projectiles stationary.

(8) After the tube breaks retrograde motion of the projectiles is observed, often covering 4^{cm}. The experiment has been spoiled by the accident, however, release of pressure being too sudden. Next day the projectiles are found to have aggregated in clusters of 2–6, irregularly along the unbroken column. Some have reached the meniscus. The drop is gone.

* The relevant formulæ are given in my paper in this Journal, III, xxxvii, p. 339, 1889.

rupture (fig. 3), until finally (fig. 4) the elastic resistance breaks down and axial rupture is the result.

To account for the motion of the projectile in fig. 4, it is to be remembered that the colloid is *solid* however soft it may be, and that therefore, in fig. 1, pressure is not transmitted upward appreciably more than a few centimeters above the meniscus. The surfaces of like stress are conoids symmetrically around the axis and with their apices in it; but these conoids rapidly become more shallow and flatten out horizontally from the meniscus upward. In fig. 4, however, the central parts of the colloid between the projectile and the apex of the meniscus is in a *discontinuous or quasi-triturated state;* i. e. solidity has here broken down with the advance of the projectile, temporarily at least, even though the whole of this part of the colloidal column is under pressure. The projectile has, as it were, ploughed out a channel.

Through this discontinuous or quasi-triturated canal pressure is transmitted as through a fluid. Hence the projectile is urged upward by hydrostatic pressure applied against its lower hemisphere and transmitted through the channel in question. The upper hemisphere of the projectile is pushed in this way continually against the unbroken coagulated colloid, whose elastic resistance is as yet too weak to resist the motion.

But the discontinuous or triturated colloid behind the projectile gradually seals itself up under pressure, which is therefore transmitted less and less fully. The elastic resistances in front thus gradually increase in relative effectiveness until rupture is no longer possible. The strain ceases to break down, the projectile stops.

10. One of the chief characteristics of the phenomenon is its repetition a dozen or more times, with gradually decreasing intensity, even at approximately constant pressure. This is less directly explained since the properties of the essentially compressible coagulate with respect to viscosity and rigidity are here brought into play, with the addition of a property to re-cohere or re-cement under pressure.

Pressure is brought up to the meniscus through mercury transmission instantaneously. It is transmitted through the coagulated colloid only to relatively short distances into the column above the meniscus. When this is ruptured, pressure is at once transmitted upward through the triturated channel, but the intensity of pressure experienced at any axial point of the colloid will be less as the point lies higher; for it is inconceivable that pressure can be transmitted through the extremely narrow channel of viscous body instantaneously. Thus a wave or a single swell of pressure gradually moves upward. Now if the colloid near the meniscus under full pressure has the

property of re-cementing into complete coherence, a gradually more marked relief of pressure will occur above the meniscus: for this pressure is slowly dissipating itself* throughout the whole upper column, access to which is shut off below. Hence in the lapse of time the original conditions will occur; there will be fresh rupture at the meniscus and a new projectile until the whole column has in this intermittent manner been subjected to constant hydrostatic pressure at the meniscus.

Briefly, pressure is transmitted upward as an advancing wave whose amplitude diminishes with the distance above the meniscus. This is followed by gradual subsidence of pressure throughout the column, and anon by a new pressure wave of like rapid motion upward and diminishing amplitude, but of less intensity; and so on.

5.

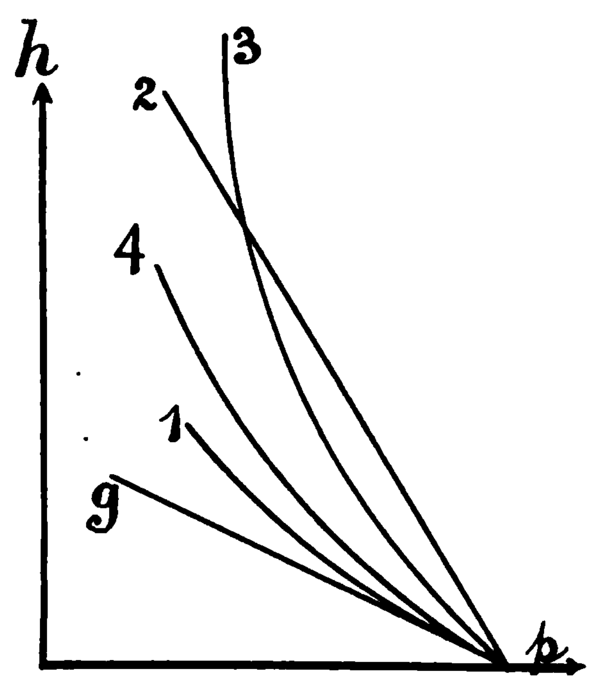


FIG. 5. Distribution of pressure, p, axially along the height, h, above the meniscus.

The annexed diagram, fig. 5, will make my meaning clearer. Let the height of the *axial* point be laid off vertically and pressure horizontally. Let g be the pressure-gradient for which rupture ensues at the meniscus (ordinate zero), pressure being here constant. Then the curve 1 may represent the distribution of pressure in the solid colloid at the instant of rupture; 2, the distribution immediately after rupture; 3, the distribution at a much longer time after rupture, when the upper part of the tube has partially accommodated itself to the new conditions, pressure increasing at the top of the colloidal column and decreasing gradually near the meniscus. Finally, in the lapse of time, 4 represents a pressure distribution having the same initial gradient g and conditioning fresh rupture.

* The volume decrement of a relatively small volume becomes the reduced volume decrement of a relatively large volume.

The scheme is to be repeated on a smaller relative scale for succeeding ruptures, and to be inverted for relief of pressure.

11. Looking at these facts as a whole, I conclude that no true compressibility (implying pure hydrostatic stress) has been measured for the coagulated colloid. The results are merely an evidence of compressibility and what is observed is a shear made possible by this compressibility. Hence the change from the very viscous fluid colloid to the coagulated (solid) colloid, looked at from the point of view of viscosity, is also a profound change in relation to compressibility. It is a change from compressibility to incompressibility relatively speaking, a change from the properties of the solvent liquid to those of the colloidal solute, supposing the body to be taken a little distant in temperature, either side of the melting point. Continuous colloid with liquid inclusions may therefore be inferred for the coagulated state, whereas in the liquid state the colloid is discontinuous.

Carus-Wilson* has ingenuously interpreted the stress-strain diagram of a metal particularly with reference to the yield points which terminate in permanent set, by the aid of Andrews' vapor-pressure diagram. The large abrupt yields of low temperatures gradually vanish as temperature rises and the metal becomes more plastic. Some such comparison might be instituted here.

12. What has impressed me as specially interesting in these experiments with coagulated colloids is their possible bearing on the dynamic manifestations of the ether. Following the lead of well known great thinkers, the hypothesis which attributes to the ether a jelly-like constitution, dynamically speaking, is familiarly in vogue to-day.

The phenomenon of the electric spark and the above experiments on the breakdown of mechanical strain as evidenced by the motion of the mercury projectiles are closely analogous. In both cases, there is an originally continuous and, I will say bluntly, a solid medium. When breakdown occurs there is in each case motion into the continuous strained medium, through the channel of broken down, discontinuous or triturated medium left in the wake. Finally there is recementation resulting in a new continuous medium.

Now the point I wish to accentuate is this, that we may distinguish between the same solid jelly-like medium in the continuous and in the discontinuous or triturated state, in the sense pointed out above; that the former transmits stress like a solid locally, showing rigidity, whereas the latter transmits it like a liquid, and in proportion as the degree of discontinuity is greater, virtually imparts hydrostatic stress. *The same ether*

*C. A. Carus-Wilson, Phil. Mag. (5), xxix, p. 200, 1890.

may therefore act, as the case may be, either as a liquid or a solid, just as, in the above experiments with gelatine, one and the same originally continuous and homogeneous body manifests itself in both roles, under the same conditions.

If this be admitted, I think that one may form at least a conception of a mechanism by which many ordinary dynamical phenomena may be looked upon as ether manifestations; and elsewhere I may endeavor to give a few tentative examples among many which I have entertained.

If in rigid dynamics, a body or a molecule can only move by breaking down the solid ether in front of it and leaving triturated ether in its wake, force* is needed to start it or in any way to change its state of motion. On the other hand, the body if sustained in place would resist such breakdown. Stress sufficient to break down the solid ether along given lines of force need not do so when the obstacle of a fixed body intervenes. In general, I hold the association of motion with the actual flux of a stress conveying fluid after the manner set forth in the present paper, not an unhappy conception, at least from the point of view of the law of the conservation of energy.

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*During motion, stress in the continuous ether in front, and pressure in the discontinuous ether behind the body or molecule, may in the first instance be supposed to be in equilibrium. Note that fixity is an essential property of such an ether.

ART. XXVIII.—*Eolian Origin of Loess;* by CHAS. R. KEYES.

THAT the formation of loess deposits has ever been aided, to any appreciable extent, by the wind, has never, in this country, gained much credence. Almost without exception the aqueous hypothesis has been accepted in explanation of the deposits in the Mississippi Valley, in spite of the many grave difficulties presented in its general application.

Of late years, some American glacialogists have begun to suspect that possibly more than one agency has been involved in the production of the loess; that water is the principal agency in some cases, and in others the wind; while in some deposits both are concerned, or both kinds exist side by side.

The accompanying notes are presented on account of their direct bearing upon the eolian side of the question. They are confined to the deposits of the Mississippi Valley. The loess bordering the Iowan and other ice sheets is not considered—only those deposits that cover the bluffs of the great rivers of the region. Hence, for convenience, they are called by the long-used name Bluff deposits.

The prime reason for excluding from the present discussion the loess of the former ice fronts, is that it doubtless had a very intimate connection with the glacial agencies. Another reason is that the observations herein recorded were made largely upon the Bluff deposits alone. From this it might be inferred that an attempt is made to differentiate two great deposits of loess—one water-laid and the other wind-driven. Such is not the case. No means of discriminating between the two kinds of loess are yet known to be formulated. Should, however, the suggestion offered for the formation of the Bluffs loess be the correct one, the presence from bottom to top in the one, and the absence or existence only near the top, in the other, of limonite tubules, and an unusually prominent jointed structure may possibly prove to be reliable criteria. The nature of the fossils should also furnish a key to discrimination.

The areal distribution of the Bluff loess is peculiar. Prof. Chamberlin has recently* stated it as follows:

"The loess is distributed along the leading valleys. These embrace not only the great valleys, the Missouri and the Mississippi, but some of the subordinate valleys, as the Illinois, the Wabash and others. The loess is found along the Missouri River from southern Dakota to its mouth; along the Missis-

* Journal of Geology, vol. v, p. 795, 1897.

sippi River from Minnesota to southern Mississippi; along the Illinois and the Wabash from the points of their emergence from the territory of the later glacial sheets to their mouths. Along these valleys the loess is thickest, coarsest and most typical in the bluffs bordering the rivers, and grades away into thinness, fineness and non-typical nature as the distance from the rivers increases. In some instances the loess mantle rises to the divide and connects with the similar deposit of an adjacent valley, but the law of progressive fineness and thinness still holds. This relationship is such as to create a very strong conviction that the deposit of the loess was in some vital way connected with the great streams of the region."

The Bluff loess is not to be confounded with other similar fine silts that are found mingled with the glacial drift occurring in many localities and that are, by some writers, called loess. Along the Missouri River the Bluff loess forms a belt fifteen to twenty miles wide. From the mouth of this river to the Iowa line at least, the deposits appear to be much heavier and the belt much wider on the left bank than on the right side of the stream. The same seems true of the Mississippi River, at least south of St. Louis. The characteristic great thickness and coarseness at the river's edge, and, away from the stream to the margin of the belt, the gradual change of the deposit to greater fineness and less depth is everywhere apparent.

Missouri's great river, in its course across the State, passes from the drift-covered region to the driftless, and crosses and recrosses from one area to the other. The belt of Bluff loess lies sometimes on driftless areas, sometimes on what appear to be older silts, and then on drift and sands having a glacial origin. It appears to occupy the tops of the bluffs irrespective of underlying formations.

The Missouri River has long been known to be a stream that is heavily ladened with silt. Vast bars exist along its course, often a mile or more wide, and continuous on one side or the other the whole length from Dakota to its mouth. These bars are bare for a period of two or three months in the spring. During this time and immediately after the June floods they constitute boundless mud-flats which soon dry.

During certain periods of the year, marked by high winds, great "dust storms" prevail on the Missouri and middle Mississippi rivers. Down or across the valley sweep the strong currents of air, catching up the light silt particles from the river bars, whirling them about, and rolling them in dense yellow clouds up and out of the valley, and over the high bluffs into the open country beyond. The heavy dust-clouds rise high into the air. A score or more miles away from the stream, the latter's course is marked by the dark pall that hangs over it.

To the inhabitants of the region these dust-clouds often become almost unbearable. Dust is everywhere. It sifts through the closed windows and doors of the houses, covering everything within. Out-doors all is yellow with an impalpably fine powder. Man and beast suffer while the storm lasts. The north and east side of the river suffers more and oftener than the south and west side. This is on account of the prevailing winds coming from the southwest in the spring and summer, when the silt bars are bare and dry. The north and northwest winds are most frequent during the winter when the ground is frozen or covered with snow.

The length of the "dust storm" varies. It may last only a single day, or it may continue through three or four days. The total number of days out of the year during which the dust clouds are driven with greater or less severity, is about thirty. During five-sixths of this period, the wind blows from the south and west.

The observations here recorded were made chiefly at Jefferson City during the years 1895–7. The measurements were made at the State capitol, which is located on the very brink of a high cliff, rising from the river's edge. The dust clouds thus came directly off of the flood-plain below. Numerous other notes were taken, but no accurate measurements made, at other places along the Missouri, as at Omaha, St. Joseph, Leavenworth, and Kansas City, and at St. Louis and elsewhere on the Mississippi.

The amount of dust brought up out of the valley at the Missouri capital and deposited on the top of the bluff was, in the several instances particularly noted, about one one-hundredth inch in a day. An open book placed in a protected nook was after a few hours so covered with dust that the print could not be distinguished. For the period of 25 days this would indicate a deposit of about one-quarter inch in a year, which is probably not far from an average for the margin nearest the river on the north side; while on the south side of the stream the total annual deposition would be very much less.

The amount deposited each day at any one place depends to a large extent upon the relation of the direction of the wind and that of the stream valley, very much less silt dust being carried out when the direction of the wind is directly across the valley than when the two directions are at an angle. In the latter case when the bare silt areas are exposed to the full sweep of a strong breeze, the dust rises high in the air and is carried far inland. The observations already noted were made chiefly at the point where there was a direct sweep of about ten miles. The daily amount carried would be, therefore,

somewhat in excess of what it would be for the whole stream. One-tenth instead of one-fourth of an inch might be perhaps more nearly correct for the mean yearly deposition. St. Joseph, Kansas City, Glasgow and St. Charles should have unusually heavy deposits of loess.

There is another factor to be taken into consideration in estimating loess deposition. Loess is not governed by the ordinary laws of erosion. While the deposits are subject to degradation and the action of running water, neither of these agencies is as destructive as in the case of most other soft materials. Loess is porous, and absorbs as a sponge most of the rain-waters falling upon it. Only the severest freshets erode it appreciably. Its capacity for resisting weathering and erosion are well shown by the perpendicular sides of road cuttings made in it, where the marks of the pick and shovel remain visible for several years.

Loess districts appear to be areas of exceptional fertility. Plant life flourishes luxuriantly even when in adjoining tracts not covered by the deposit only a scant vegetation is supported. The peculiar porosity of the loess gathers in the maximum amount of water, holds it, and gives it out again gradually, during the dry season. The belt is one of unusual dampness and there is within its limits always an abundance of moisture for plant life.

The plant roots penetrate the loess to great depths, and this is perhaps the main cause of the marked vertical cleavage developed in many of the deposits. The roots, instead of spreading out a few inches beneath the surface as in most soils, in loess appear to penetrate straight downward much farther than is usually the case. In decaying, the exterior corky layer of the rootlets lasts much longer than the other parts. As the interior disappears the outer tube finally collapses, leaving a flat band or ribbon-like film that long resists further decay and finally only the insoluble mineral particles. If it can be shown that the cleavage is eminent from bottom to top of some deposits and only at the top of others, a criterion might be established for distinguishing between wind and water deposits.

The dense vegetable growth well protects the loess from the destructive effects of wind and water. When once deposited the silt particles are only with great difficulty disturbed. Silt dust blown up from the valley strikes the thick vegetation and is acted upon in the same way that it is in water when the current is checked. The particles come to rest around the roots and gradually build up the ground. Each year's vegetation is on a little higher level than the last.

A characteristic feature of some loess deposits is the small, cylindrical, concretionary masses that are commonly called loess

tubules. They are sometimes lime; sometimes iron. The origin of the latter appears to have been overlooked. As the plant roots begin to decay they accumulate around them crystalline coatings of iron pyrites, which finally form little pipes one-eighth to one-fourth of an inch or more in diameter, and several inches long. The pyrites soon changes to limonite. Along the Missouri River, all stages of tubule formation are readily made out—from the decaying rootlet, with a thin film of pyrites on it, though the crystalline aggregate of pyrites, to the pyrite-limonite cylinder. Around all of the roots pyrites does not form. Whether or not the pyrites is deposited on the roots of a particular plant is not known. The fact that the tubules are very abundant in certain spots and sparingly distributed or absent altogether in others suggests that the nature of the plant has something to do with their occurrence.

As a possible means of discrimination between water-laid and wind-formed loess the tubules may prove an important criterion. Should they occur at all levels in a deposit, the indication would be that it had accumulated among plant growths; whereas if they are found only at the top, it would be suggested that the vegetation did not cover successively every layer of loess, but only, as at present, the upper part.

The chemical process of the accumulation of the iron pyrites around the decayed roots of the plants in the loess is doubtless analogous to the formation of the principal sulphide ores of lead, zinc and iron in the same region of south Missouri. It is a comparatively rapid process under favorable circumstances, different rates of deposition prevailing with the different ores. A decade or even less is probably ample time for the accumulation of iron pyrites to a thickness of a quarter of an inch. The process is in all likelihood in operation at the present time and the deposition of pyrites in tubules, as well as the zinc and lead in the rock crevices, is going on to-day as rapidly as it has ever gone on in the past.

The fossils of the loess have never received the critical attention that they deserve. A careful consideration of them promises very fruitful results. Their real significance and possible usefulness as a means of discriminating between loess deposits having different origins can only be merely alluded to here. In proportion to the great amount of study that the loess has received from many individuals, it is a rather remarkable fact that the fossils have received so little notice. What little special consideration they have had is contradictory, and is from a biological rather than from a geological standpoint. R. E. Call and B. Shemik have both collected largely the loess fossils; but the conclusions reached are diametrically opposed. The one argues that the organic remains when compared with

the same species now living in the same region presented a marked depauperation, attesting a much more rigorous climate in glacial times than at present. The other writer, after examining a much greater amount of material, from a very much larger area, shows that the loess fossils are not only not smaller in size, but if anything slightly larger than existing individuals.

Some fifty species of animal remains are credited to the loess formations of the upper Mississippi Valley. Among these are several vertebrates. Whether or not the latter really belong to the loess or are to be regarded as having been incorporated by slipping and over wash of the deposit, is not known.

Molluscan shells form the great bulk of the loess fossils. With the possible exception of half a dozen isolated exceptions none of the species are bivalves. The large majority are land forms, with a few water species that do, however, inhabit small temporary pools. In the Bluff loess more than nine-tenths of the total number of individuals belong to species that are found only in unusually damp situations. They are those species that to-day occur most abundantly in the loess areas. The species having an optimum habitat that is not excessively moist have not been observed to occur abundantly in the Bluff loess, though they flourish in the country bordering the loess belts. These loess fossils are apparently those forms that have lived among the plants of the belt. On the death of the animals the shells simply dropped down on the ground beneath and were covered.

On the other hand, there occur in the loess of the ice fronts shells of mollusks that do not now live in the region. Such are *Helicina occulta* Say, *Patula strigosa* Gould, the boreal species of Pupa, and other northern forms. The loess fossils should be studied with reference to their possible use as a means of discriminating between loess deposits having different origins.

The presence of vertical root remains and limonite tubules, from the bottom to the top of the Bluff loess, the luxuriousness of vegetation covering the loess belts, the "dust" storms on the larger silt-ladened streams, the peculiar relations existing between the prevailing winds and the distribution of the loess deposits, all point to fruitful sources of inquiry regarding one of the most obstinate problems in Pleistocene geology. A possible means is suggested of discriminating between deposits lithologically similar, that are doubtless formed by very different agencies and under very different conditions. The inference to be drawn is that the eolic processes have been at work upon certain deposits in the Mississippi Valley in a manner and to an extent that has been, heretofore, little appreciated.

ART. XXIX.—*On Dikes of Felsophyre and Basalt in Paleozoic Rocks in Central Appalachian Virginia;** by N. H. DARTON, U. S. Geological Survey. With notes on the Petrography by ARTHUR KEITH, U. S. Geological Survey.

THE occurrence of igneous rocks in the central and northern Appalachians is very unusual, for the detailed work in various portions of the province from Alabama to New York has only resulted in the discovery of a dike in central Pennsylvania and the small group of dikes west of Staunton, Virginia, which I described in 1890.†

1.

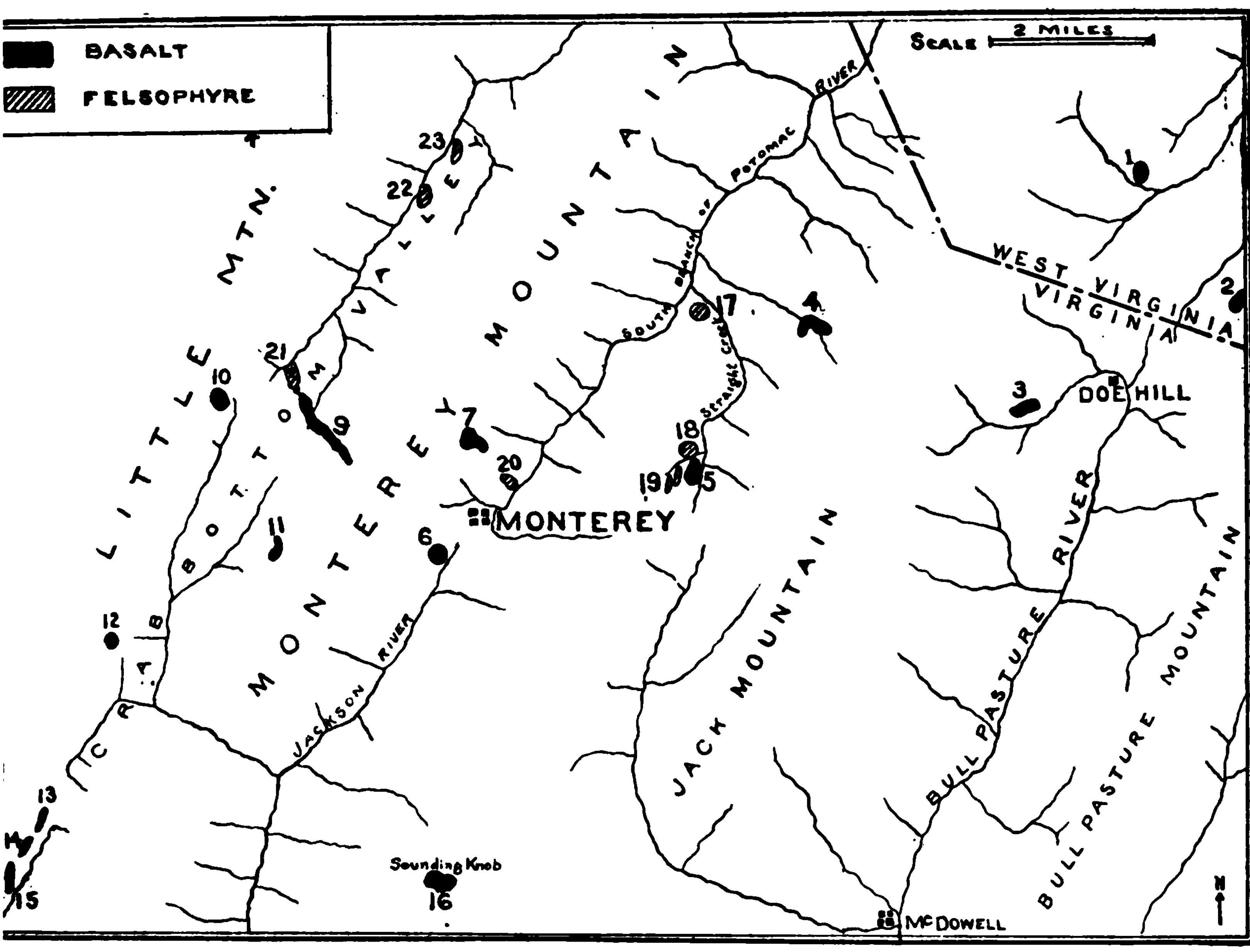


FIG. 1.—Map of a portion of central Appalachian Virginia showing location of dikes.

In 1896 I had opportunity to extend my observations farther west and discovered‡ additional basalt dikes and a very interesting series of dikes of an acid character which Mr. Keith has found should be classified as "felsophyre." The region in which all these dikes occur is an area of about 120 square miles, lying mainly in Highland County, in the central western portion of Virginia. Two dikes were found in the adjoining portion of Pendleton County, West Virginia. The region is in the

* Published by permission of the Director of the U. S. Geological Survey.

† This Journal, vol. xxxix, pp. 269–271, with petrographic notes by Mr. J. S. Diller.

‡ Announced at meeting of Geological Society of America, Dec. 28, 1896.

center of Appalachian uplift which in the Crabbottom valley west of Monterey attains unusually great altitude.

The distribution of the rocks of each of the two principal varieties is shown in Fig. 1.

The basaltic rocks at Nos. 1, 2, 3, 4 and 6 were described in the publication above referred to. They are all small dikes, Nos. 2 and 4 cutting Lewistown (Heldersberg) limestone, and No. 5 rising at the contact of Romney shale (Marcellus) and Monterey (Oriskany) sandstone. Nos. 4 and 5 are associated with friction breccias composed of a variety of more or less altered sedimentary rocks. The other dikes of basalt discovered in 1896 are of similar character but some of them are of larger size. The outcrop No. 16 at Sounding Knob is on the top of a high anticlinal mountain of Tuscarora (Medina-Oneida) quartzite, the igneous rock rising as a steep-sided neck about 80 feet above the crest line. The altitude of its summit is nearly 4,500 feet. The outcrop No. 9 is a dike which extends down the west side of Monterey mountain in the great Crabbottom anticline cutting through Martinsburg (Hudson) shale and Shenandoah (Lower Ordovician-Cambrian) limestones. Its width varies from 30 to 120 feet and its course is nearly due northwest. The dikes Nos. 13, 14, and 15 are along probably one line of intrusion trending northeast, but they appear not to be connected at the surface. At No. 15 there are showings of friction breccia of somewhat altered sedimentary rocks.

The acid rocks have only been observed within a radius of a few miles from Monterey. The dikes are small and inconspicuous. The best exposure is on the upper forks of Straight Creek, three miles east-northeast of Monterey. Here the rock occurs in several large white masses rising in a low knoll with an area of only a few square yards. The material is hard, fresh, and very characteristic. A few rods south at No. 5 there is an exposure of basalt, and a short distance west are two small exposures of narrow dikes of the weathered acid rock. They are all in Rockwood (Clinton) shales. The relations of the rocks to one another in these exposures could not be determined, owing to lack of continuity of outcrops. Near the mouth of Straight Creek, at No. 15, there is a small exposure of the acid rock cutting the Monterey sandstone. The dike near Monterey, No. 20, is exposed along the roadside about a half mile northeast of the village cutting Romney shales. It can only be traced for a few yards. In the Crabbottom valley three exposures were discovered, at Nos. 21, 22, and 23, in the Shenandoah limestone along the road from Hightown to New Hampton. A half mile north of Hightown, at No. 21, two small dikes of decomposed and weathered felsophyre are seen in the roadcuts penetrating Shenandoah limestone. At Nos. 22 and 23 several other small dikes are exposed. They are

deeply decomposed. It is possible that Nos. 21, 22, and 23 are along one line of fissure. If so, it is one coincident with the crest of one of the highest anticlinals of the central Appalachian region. No. 21 appears to be in the same fissure as the basalt dike No. 9, but the continuity of the two rocks could not be traced, owing to woods and debris. Further details of the occurrence and geologic relations of these dikes will be shown in the Monterey folio of the Geologic Atlas of the United States now in course of publication by the Geological Survey.

Notes on the Petrography.

By Arthur Keith.

The eruptive rocks above described by Mr. Darton comprise two classes of very distinct nature and appearance. The first, or basic type, is similar in all respects to the basic rocks occurring in dikes and sheets in the Jura-trias sediments and to a less degree in the Paleozoic and Archean rocks. The first material obtained in this region was described by Mr. Diller.* Subsequent investigations by Mr. Darton revealed additional dikes and the existence of a second class of eruptives which are first described in this paper. This later discovered group is of a decidedly acid composition and more nearly approaches the granite-rhyolite than any of the other large rock families.

Appended is a chemical analysis of a typical sample of the acid rock, as determined by W. F. Hillebrand in the Laboratory of the U. S. Geological Survey. For comparison a partial analysis of a typical basic rock is adjoined as determined by the same analyst.

	No. 18.	No. 5.
SiO_2	69·56	43·38
TiO_2	·31	
Al_2O_3	15·52	
Fe_2O_3	1·67	
FeO	1·19	
MnO	·07	
CaO	1·20	14·02
SrO	trace	
BaO	·10	
MgO	·41	
K_2O	4·68	·56
Na_2O	4·46	1·64
Li_2O	trace	
H_2O below 110° C.	·34	
H_2O above 110°	·67	
P_2O_5	·08	
CO_2	none	
S	trace	
Cl, Fl,	not tested for	
	101·26	

*This Journal, vol. xxxix, pp. 270–271.

The percentage of silica in the typical specimen of acid rock No. 18 is seen to be entirely characteristic of granite. The same may also be said of the other chemical constituents. Silica only appears as free quartz in the groundmass, being entirely absent from the phenocrysts. The amount of it in the groundmass, moreover, is relatively small. In this feature of inconspicuous quartz, taken in connection with the trachytic aspect of the rock in the hand specimen, these acid eruptives resemble the syenite-trachyte family. The minerals, however, and the chemical proportions show that it is of the granite family, and in its name the porphyritic aspect should be recognized for a complete description. The grain of the groundmass is micro-crystalline, but since it has not the true granitic aspect, the term "granite" or its allied terms cannot be properly applied. Neither does the groundmass contain glassy portions or any matter which can be definitely stated to be felsitic, owing to the alterations of the rock due to weathering. As a whole, however, the rock is more nearly a porphyritic felsite than anything else, and should, therefore, be designated as a fine "felsophyre."

The basic eruptives exhibit no changes, either in chemical composition or in component minerals, from the usual types of the Jura-trias basic rocks.

A brief description of each of the specimens and thin sections follows, from which the variations of the rocks can be seen. The localities from which these sections are taken are shown upon the accompanying map, fig. 1 (p. 305), by corresponding numbers.

Basic Rocks.

No. 5.—This rock in the hand specimen consists of a rather coarsely crystalline aggregate in which porphyritic individuals of olivine and augite are prominent. The groundmass is fine and of a dark gray or black color. On the weathered surfaces decay has brought out the crystals of feldspar slightly. The olivines are green and yellowish brown in color and appear unaltered. The greenish color in some of the olivine is due perhaps to small replacement by chlorite. The augites are of a dark gray or blackish gray color and show fresh cleavage faces. Aside from these two porphyritic minerals and the small feldspars upon the weathered surface, no other minerals cau be detected in the hand specimen.

Under the microscope this rock differs greatly in appearance from the following sections and has a very decided porphyritic character. The phenocrysts are composed of augite and

olivine; the former are of a yellowish gray color with darker, brown borders, the latter in particularly brilliant colors and frequently with sharp, crystal faces. The groundmass is very fine and consists of plagioclase, magnetite, augite, and a little olivine. In the case of the olivines, there seems to be a gradation between the coarse phenocrysts and the grains in the groundmass. Considerable numbers of magnetite crystals are included in the augites near their borders, and also appear to a limited extent in the olivine. Slight decomposition has produced stains of limonite and small growths of chlorite in the cracks of the olivine. The large percentage of magnetite in groundmass renders it comparatively opaque. This rock bears a strong resemblance to the section (No. 1) described by Diller.

No. 11.—This specimen is somewhat weathered, being taken from the surface, and contains many faces stained with iron. It is of a dull gray color and very finely crystalline. No porphyritic minerals appear and the only minerals which can be detected by the magnifying glass are here and there small feldspar laths or an occasional feldspar cleavage face.

The texture of this rock, as seen under the microscope, is uncommonly fine for the basic eruptives of this region, and the mineral composition is likewise more than usually simple. The bulk of the rock consists of a fine mass of plagioclase crystals with a marked parallel arrangement. Intermingled and in part included within these feldspars are great quantities of minute, black crystals, the majority of which are magnetite. The only other constituents which occur in any quantity are the small individuals of mica, apparently biotite, which are compressed between the feldspar crystals and many minute individuals of augite. Considerable secondary limonite is present, probably derived from the decomposition of the iron oxides. Certain very small grains have the appearance of olivine, but are difficult of determination. The chief characteristic of the rock is its high feldspathic content and the parallel arrangements of the feldspars, which indicate flow structure. No traces of glass were observed.

No. 15.—This rock is of fine grain and dark gray to black color. Weathering extends to a depth of half an inch from the surface and produces a light gray color with considerable staining of iron. At the same time the attitude and size of the feldspar crystals in groundmass is brought out by kaolinization. In the fresh portions crystal faces and cleavage planes of the feldspar are very frequent. From this groundmass porphyritic crystals of augite of considerable size stand out prominently. Smaller porphyritic crystals of olivine are present in less numbers. Fine black specks of magnetite are dotted through the

rock and appear most prominently upon the lighter weathered surfaces.

In the thin section appears the ordinary ophitic arrangement of the Piedmont diabases. The texture is rather finer than usual in these rocks. The minerals consist of a great mass of feldspar intergrown with and enclosing numerous magnetite crystals and patches. Many crystals of olivine of somewhat porphyritic appearance interrupt the ophitic structure, and around their borders the feldspar laths have a tendency to parallelism. Secondary decomposition has proceeded to considerable extent in these olivines, resulting in patches and cracks filled with chlorite and leucoxene. In many cases limonite is deposited in the same situations. Frequent small individuals of augite appear between the feldspar laths, and small, patchy individuals of calcite are also to be seen. These do not usually have crystalline outlines. One crystal of augite of somewhat prophyritic appearance is intergrown with magnetite.

No. 16.—Few macroscopic characters are well defined in this rock. It is of a dark gray color, weathering to a lighter gray upon exposure. The feldspars of the groundmass, which are extremely fine and invisible upon fresh surfaces, are brought out in the lighter gray portions affected by the weather. Porphyritic crystals of augite are sparsely distributed through the rock, and patchy phenocrysts of feldspar appear here and there in the groundmass. In one layer these have a tendency to an amygdaloidal appearance. A few scales of biotite are also to be detected. The presence of olivine is shown in the partly weathered portions by a greenish color of the rock, and also a few phenocrysts of the same mineral are sparingly distributed.

In this section the rock is holocrystalline and displays no evidence of glass. The plagioclase laths are comparatively small and their arrangement is more nearly parallel than ophitic. The body of the rock is mainly composed of these crystals. Intermingled with them are fine crystals of augite, olivine, and magnetite, the latter in unusual abundance. No additional features of interest appear in this section.

Acid Eruptives.

In the hand specimen these eruptives have a decided light gray color, which passes, in the weathered specimens, to white or yellowish white, according to the amount of decomposition of the feldspars. The texture is in general fine. The groundmass is light gray in color; from this stand out the white feldspar and the dark biotite and augite phenocrysts. Decay

first attacks the albite phenocrysts, which are kaolinized, as a rule, even in the comparatively fresh specimens. Thus two classes of phenocrysts are distinguishable among the feldspars on the hand specimens, these being the weathered albites and the clear, unaltered orthoclase. These general characteristics are shared by all of these acid eruptives thus far discovered, and the chief variations occur in the coarser or finer texture of the phenocrysts.

No. 18.—In this specimen is found the coarsest crystallization of these acid eruptives. The groundmass is of the same dove color as in the preceding rock and has an equally fine grain. The proportion of phenocrysts of biotite and feldspar is unusually great, and perhaps one-third of the rock is composed of them. The biotites appear in flat, hexagonal crystals with sharp outlines. The division of the feldspars into kaolinized and fresh individuals is strongly accented. The rounded exteriors of the fresh feldspar phenocrysts are so clear and transparent as to strongly resemble quartz; on their broken surfaces, however, the cleavage faces stand out prominently. A few phenocrysts of augite are also to be seen, but are very far inferior in numbers to the other minerals. The phenocrysts of feldspar and biotite are about equal in amount.

In the corresponding thin section the minerals are in a much fresher condition than in most of the sections and more satisfactory determinations can be made. The general appearance of the rock is the same as in the other sections, and its simple composition is admirably shown. It is seen to consist of a microcrystalline groundmass, with phenocrysts of orthoclase, plagioclase, and biotite. In the arrangement of the crystals of the groundmass no order or system is to be discovered. The phenocrysts are perhaps slightly larger and more frequent than common in these rocks, but they consist of the usual minerals, feldspar and biotite. The outlines are sharp and clear and the crystallographic planes are, in many cases, well defined. The biotite crystals are of a greenish brown color and strongly pleochroic, and occasionally they contain small portions of the feldspathic groundmass. A slight tendency to parallelism also appears in them. In one case the biotite and feldspar phenocrysts are intergrown. The feldspar in this case appears to be orthoclase. The groundmass is a microcrystalline aggregate, chiefly of feldspar, quartz, and many extremely small crystals of magnetite or ilmenite. Such of the feldspars as can be determined comprise both plagioclase and orthoclase. No traces of glass are to be seen. There appear to have been practically no disturbances of a dynamic nature in the body of the rock, as the cracks in the larger minerals are very few, and the extinctions are not wavy. One biotite crystal shows a slight

bending, as if due to some movement after its formation. In the groundmass there is a small amount of secondary chlorite in extremely small particles, and an even smaller amount of muscovite, both apparently due to decomposition by weathering.

No. 17.—This rock has the typical aspect of the acid eruptives. It consists of an extremely fine groundmass of a light gray or dove color, through which are distributed large phenocrysts of feldspar and smaller ones of biotite. The feldspar phenocrysts do not differ so greatly from the color of the groundmass as to be conspicuous. Dark scales of the biotite, however, stand out very prominently. The feldspar phenocrysts are in part bright and clear and in part kaolinized, thus separating the feldspars into two groups. The biotites are in flat, hexagonal crystals and are very sharp and clear.

No features appear in this section which were not observed in No. 18 except a slight tendency to parallelism of the feldspar crystals in the groundmass, particularly around the outlines of the phenocrysts. This is quite marked in several cases. The phenocrysts consist of biotite and plagioclase. In a few cases doubtful orthoclase appears, in which the mineral was nearly removed in the making of the section. The amount of magnetite is decidedly less than usual, and some fine chlorite, apparently derived from original biotite in the groundmass, marks the progress of decomposition by weathering. A little of the groundmass is included in the phenocrysts, but usually their outlines are sharp and perfect.

No. 19.—This specimen, like the preceding one, is badly weathered. The general gray or dirty white color of the rock is varied by the limonite stains at the surface and in the phenocrysts, and by the prominent black biotite phenocrysts. Many of the large feldspar crystals have been entirely removed, leaving only the cavities which they once filled. The biotite crystals appear as fresh and unaltered as in the other specimens examined. The phenocrysts in general are slightly smaller than in the other specimens. This is true, perhaps, of the biotite in greater degree than of the feldspars. The proportion of the rock which the phenocrysts make up is somewhat less than usual, the biotite crystals in particular being plainly fewer. One or two doubtful cases of augite were also observed.

In this slide the proportion in size between the phenocrysts and the individuals of the groundmass is considerably changed. The phenocrysts are much smaller, while the groundmass is so much coarser that most of its individuals appear distinctly as separate crystals. The two series, however, are still greatly different in size and the rock is accordingly porphyri-

tic. The phenocrysts are of the same minerals, biotite, however, being comparatively scarce. The feldspar phenocrysts also have a tendency to develop in rudely radiating bunches of stubby crystals. These are, for the most part, plainly plagioclase, but there are many doubtful instances in which it is probable that the mineral is orthoclase. Much the greater part of the groundmass consists, as before, of minute plagioclase crystals closely felted together and clamping small individuals of biotite, quartz, and the iron oxides. In the latter considerable decomposition has taken place, giving rise to limonite and limonite stains, and outlining by these colors the network of feldspar crystals. Occasionally inclusions of the groundmass are seen in the feldspars, but they are more rare than in the preceding sections. The feldspar phenocrysts are sharply outlined and the crystal faces seem to have suffered practically no resorption.

No. 21.—The material of this specimen is very badly decomposed, but owing to the striking texture of the rock, its nature is seen as clearly as in the fresh specimens. The same grayish groundmass appears, in which minute feldspar individuals can be detected by their weathering. The usual phenocrysts of feldspar and biotite are conspicuously developed and attain sizes as great as in the preceding section. Only one or two augite crystals, however, were detected. The decomposition of the ferruginous minerals has stained the exterior of the rock, and limonite has concentrated in those phenocrysts which were most thoroughly decomposed, giving them a yellowish appearance instead of the white color usual in the fresh rock.

This section is of a strongly porphyritic aspect. The phenocrysts of biotite are large and well-shaped; areas representing probable feldspar were nearly worn away in the preparation of the section on account of its weathered condition. The groundmass consists of a finely felted mass of feldspar, chiefly plagioclase, with many small crystals of biotite, ilmenite or magnetite, and a little quartz. Owing to the weathered condition of the rock, the ferruginous minerals have oxidized considerably, and stains and bodies of limonite are frequent. Portions of the feldspathic groundmass are enclosed in the biotite crystals. These latter are, for the most part, fresh and show slight decomposition to chlorite. The brown color and the pleochroism are both strong.

No. 22.—This section, like the preceding, is much weathered and deeply stained with limonite. It has also a strongly porphyritic appearance. The phenocrysts consist of plagioclase, doubtful orthoclase, biotite, and augite. The crystals are large and the outlines are sharp and clear. Included in the augite

and in the plagioclase are portions of the groundmass of greater or less size and also of biotite and magnetite. In this section decomposition by weathering has proceeded to great lengths, and the smaller feldspars in the groundmass, and to some extent the phenocrysts, have decomposed with a production of considerable chlorite, calcite, and limonite. The groundmass consists of the finely felted, holocrystalline aggregate of plagioclase, orthoclase, biotite, augite, magnetite, and calcite with a few crystals of quartz.

General Nature of the Dikes.

The general distribution of these acid and basic dike rocks in an east and west belt has been already mentioned. Beyond that rude arrangement it is difficult to decipher anything systematic. In the basic rocks, while they all have the same physical appearance, contain the same minerals, and bear a decided family resemblance to each other, there are three distinct types of texture. These are the basaltic, the diabasic, and the porphyritic textures. The porphyries appear upon the west side of Jack mountain, one of which has been described by Diller and another in these pages. The rock with the ophitic texture of diabase appears in section 15, in one of the southwestern outcrops. The remainder are intermediate in appearance between these, sometimes inclining to one type, sometimes to the other. In these also the feldspars have frequently a decided fluidal arrangement, both through the body of the section in a general way, and around the larger crystals. The same arrangement appears to some extent in the porphyritic type. Section No. 16, taken from Sounding Knob, displays the most clearly fluidal arrangement. In this area of the basalt it is evident, from the appearance of the rock mass upon the ground, that it was an old volcanic neck and was produced by an injection of considerable height. Aside from these features, there seems to be no arrangement discernible.

As the chemical analysis shows, these basic eruptives are of the same class as those which appear in direct connection with the Jura-trias sediments. Under the microscope, also, they have the same appearance and contain the same minerals. Inasmuch as these Jura-triassic eruptives in some cases pass from the Jura-trias sediments into the Silurian sediments, the occurrences here are plainly in the same line. They offer, therefore, nothing especially novel. The acid eruptives, however, constitute an entirely new class of such phenomena. They have not been observed, within the writer's knowledge, at

least in the southern Appalachians. Rocks of somewhat similar appearance have been found by the author in various portions of the Archean mass east of the Silurian sediments, but the resemblance of the two groups is not sufficient to warrant any deductions. Beyond the fact of their eruption through the Silurian sediments and their location upon the great anticlinal regions, there are no facts of distribution which throw any light upon their cause. In one case, at Hightown, the acid lava appears to occupy the same fissure as that filled in one portion by the basic lava. In this case the acid eruption may represent an opening upon the same line of weakness at a separate time, or it may occupy a fissure slightly divergent from the basic fissure, the contents of each not coming into actual contact. The exposures upon the ground are insufficient to settle this question. Considerable variations of texture appear in these acid rocks, but no system is to be observed in their distribution other than a growing fineness toward the boundary of each body. In their extremely weathered condition, as shown by Mr. Darton, they easily escape observation and they may possibly be more widely distributed than is now known.

ART. XXX.—*Diaphorite from Montana and Mexico;* by L. J. SPENCER.

DIAPHORITE being a rare mineral known from only a few localities, it seems worth while to record two new occurrences.

A stephanite specimen from the Lake Chelan district, Okanogan County, Washington, recently acquired by the British Museum, shows crystals of dolomite, quartz, galena, pyrargyrite and diaphorite. On a measured crystal of diaphorite the following forms were noted: a, b, m, π, x, ψ, y, ω and (212).

The Mexican crystals of diaphorite from Santa Maria de Catorze, in the state of San Luis Potosi, are associated with crystals of miargyrite, dolomite, quartz, pyrites and blende; they are very rich in faces and several new forms have been noted.

Except for the lamellar twinning sometimes present on freislebenite, the three minerals andorite, diaphorite and freislebenite are very similar in appearance, and can only be distinguished by measuring the crystals. Between them an interesting morphotropic relation exists, which reminds one of the relation between humite, chondrodite and clinohumite.

		Sp. gr.	Chem. comp.
Andorite	$\frac{2}{3}b : a : c = 0{\cdot}9846 : 1 : 0{\cdot}6584$	5·35	$RS . Sb_2S_3$
Diaphorite	$2a : b : c = 0{\cdot}9839 : 1 : 0{\cdot}7345$	5·9	....
Freieslebenite	$\frac{5}{8}a : b : c = 0{\cdot}9786 : 1 : 0{\cdot}9277$; $\beta = 87^\circ 46'$	6·3	$5RS . 2Sb_2S_3$

The vertical axes are in the ratio 9 : 10 : 13. The same relation can also be extended, though less perfectly, to stibnite on the one side, and to bournonite, etc., and galena on the other. This suggests that in composition also diaphorite should fall between andorite and freislebenite. Brongniardite,* which has an intermediate formula, namely $2RS . Sb_2S_3$, agrees in specific gravity and in its external characters with diaphorite: it therefore seems highly probable that brongniardite and diaphorite are identical. It is hoped to be able to collect sufficient material (measured crystals of diaphorite) for analysis, in order to definitely prove the identity here suggested.

British Museum of Natural History.

* The so-called cubic crystals of brongniardite have recently been shown to be stanniferous argyrodite (Min. Mag., 1898, xii, p. 5).

ART. XXXI.—*On the Detection of Sulphides, Sulphates, Sulphites and Thiosulphates in the presence of each other;* by PHILIP E. BROWNING and ERNEST HOWE..

[Contributions from the Kent Chemical Laboratory of Yale University—LXXIV.]

SOME three years ago R. Greig Smith* published a method for the detection of sulphates, sulphites and thiosulphates in the presence of each other, which promised much toward the solution of this most difficult problem. The method may best be described in the author's own language: To a solution of the salts of the above mentioned acids "barium chloride is added in excess, together with a good quantity of ammonium chloride, which, like many salts of ammonium, potassium and calcium, acts as a flocculent or coagulant, and facilitates the filtration of the barium sulphate. Hydrochloric acid is next added, drop by drop, until it is evident that there is no further solution of barium sulphite and thiosulphate, and that only the sulphate remains undissolved; the solution is then filtered through a moistened double filter paper, which should be free from 'pin holes.' The filtrate will probably be clear, but if not it should be returned to the filter for a second filtration. When too much thiosulphuric acid is present, the clear filtrate will visibly become clouded, or from being whitish will become more opaque; if this occurs the solution should be thrown out, and a fresh portion made more dilute. A solution of iodine is added to half of the filtrate until the color is of a permanent yellow tinge; a white precipitate indicates the presence of a sulphite which has been oxidized by the iodine to sulphate. In the absence of a decided precipitate traces of sulphite may easily be detected by comparing the treated and untreated halves of the filtrate—a procedure which very often saves a good deal of time, as it is unnecessary to wait until a clear filtrate is obtained. The two halves are mixed, and if the yellow color disappears more iodine is added, the solution filtered and the filtrate divided into two halves as before. With a slight turbidity filtration may be omitted. Bromine water is added to one of the halves when any thiosulphate in the original solution shows itself as a white precipitate of barium sulphate, readily seen on comparing the two test tubes. The thiosulphate is by iodine converted to tetrathionate, which is oxidized by bromine water to sulphate." Three objections to this method as described will readily occur to the reader: first, the readiness with which the thiosulphate is decomposed by free hydrochloric acid; second, the comparatively large

* Chem. News, vol. lxxii, 39.

amount of acid necessary to effect the complete solution of the barium sulphite and thiosulphate when precipitated with the sulphate as compared with the amount required to prevent the precipitation ; third, the lack of delicacy necessitated by a comparison of portions of a colored solution in looking for small precipitates. The work to be described was undertaken to overcome these difficulties and to test the accuracy of a modified method. Solutions of potassium sulphite and sodium thiosulphate were made approximately decinormal and standardized in the usual manner against an iodine solution of known value. It was found that by making a solution containing sulphates, sulphites and thiosulphates very faintly acid, the sulphates and thiosulphates were held completely in solution when the barium sulphate was precipitated. The extreme sensitiveness of a thiosulphate to the decomposing action of free hydrochloric acid suggested the possible substitution of acetic acid to hold the sulphites and thiosulphates in solution. This being a weaker acid, we hoped to avoid the decomposition of the thiosulphate into sulphur and sulphurous acid, or at least to delay the decomposing action. The results of these experiments appear in the following table :

TABLE I.

	Volume cm^3 of water.	Hydrochloric acid (1 : 4) drops.	Acetic acid. drops.	$Na_2S_2O_3$ taken. grm.	Result.
1	10	2	..	0·01	No sulphur in 20 minutes.
2	10	2	..	0·1	Sulphur in 45 seconds.
3	100	3	..	0·1	Sulphur in 15 minutes.
4	10	..	8	0·01	No sulphur in 20 minutes.
5	10	..	8	0·1	Sulphur in 90 seconds.
6	100	..	10	0·1	No sulphur in 20 minutes.
7	100	..	10	0·25	Sulphur in 15 minutes.
8	100	..	10	0·5	Sulphur in 60 seconds.
9	100	..	10	1·0	Sulphur in 30 seconds.

From these results it would seem that the decomposition of a thiosulphate is more rapid in presence of hydrochloric acid than in presence of a much larger amount of acetic acid.

Our next experiments were directed toward a determination of the effect of adding stannous chloride to bleach the color of the free iodine and bromine used in the oxidation and of acidifying with acetic acid, before treating with barium chloride. That is to say, the process as we used it, consisted in acidifying the solution to be tested with acetic acid, adding barium chloride, filtering to remove precipitated sulphate (always present in the sulphite), adding iodine to the filtrate until the color was permanent, bleaching with stannous chlor-

ide, filtering off the sulphate which represents the sulphite originally present, adding bromine in excess to the filtrate and again bleaching with stannous chloride to increase the visibility of the sulphate which now represents the thiosulphate originally present. The details of experiments in which the sulphite was taken alone and oxidized with iodine are given in Table II.

TABLE II.

	K_2SO_3 taken. grm.	Volume of water. cm^3.	$BaSO_4$ precipitated after oxidation with iodine.	Remarks.
(1)	0·1	10	Very abundant	Plainly visible before adding $SnCl_2$.
(2)	0·01	10	Abundant	Plainly visible before adding $SnCl_2$.
(3)	0·001	10	Distinct	More distinct after adding $SnCl_2$.
(4)	0·0005	10	Fair	Hardly visible before adding $SnCl_2$.
(5)	0·0001	10	Faint	Invisible before adding $SnCl_2$.

A corresponding series of experiments was made in which hydrochloric acid was substituted for acetic acid and essentially the same results were obtained.

A similar series of experiments was made to test the effect of treating the thiosulphate in an acidified solution, first with iodine and then after filtration (if a precipitate had formed) with bromine. In the experiments of division A hydrochloric acid (a few drops) was added before treating with barium chloride, and in those of division B acetic acid was used similarly. Stannous chloride was employed to bleach the excess of iodine and bromine.

TABLE III.

	$Na_2S_2O_3$ taken. grm.	Volume of water. cm^3.	$BaSO_4$ precipitated by action of iodine.	$BaSO_4$ precipitated by action of bromine.	Remarks.
			A.		
1	0·1	10	Distinct	Abundant	Sulphur separated in 30 seconds.
2	0·01	10	Faint	Abundant	No sulphur in 90 seconds.
3	0·001	10	None	Distinct	No sulphur in several minutes.
4	0·0005	10	None	Faint	No sulphur; $SnCl_2$ necessary.
5	0·0001	10	None	Very faint	No sulphur; $SnCl_2$ necessary.

B.

1	0·1	10	Faint	Abundant	No sulphur separated in 1 min.
2	0·01	10	None	Abundant	No sulphur separated in several minutes.
3	0·001	10	None	Distinct	No sulphur.
4	0·0005	10	None	Faint	No sulphur; $SnCl_2$ necessary.
5	0·0001	10	None	Very faint	No sulphur; $SnCl_2$ necessary.

From these experiments the advantage of the use of acetic acid becomes apparent, as does also the use of stannous chloride in increasing the delicacy of this indication, so that a small fraction of a milligram may easily be detected.

If relatively large amounts of thiosulphate are present with small amounts of sulphite, we have sometimes found it advantageous to manipulate so that even the slow decomposition of the thiosulphate by acetic acid may be avoided by first attempting precipitation with barium chloride in a dilute ammoniacal solution. By this method the barium sulphate and sulphite are separated from the thiosulphate and identified—the sulphate by its insolubility in dilute hydrochloric acid, and the sulphite by the action of iodine upon the acid filtrate from the barium sulphate. After filtering, the thiosulphate may be detected in the filtrate by the use of iodine and bromine as described above. Table IV gives some results by this treatment.

TABLE IV.

	$Na_2S_2O_3$ taken. grm.	$BaSO_4$ precipitated by iodine.	$BaSO_4$ precipitated by bromine.	Remarks.
(1)	0·1	None	Abundant	
(2)	0·01	None	Good	
(3)	0·001	None	Fair	$SnCl_2$ necessary.
(4)	0·0005	None	Faint	$SnCl_2$ necessary.
(5)	0·0001	None	None	

As will be seen, the test for the thiosulphate by this method of treatment is not so delicate, probably on account of mechanical holding of the barium thiosulphate by the precipitated sulphate and sulphite.

Having determined the limits of accuracy of the method as applied to the sulphite and thiosulphate taken separately, our next experiments were directed toward an investigation of the

working of the method when these two acids are found together in solution. Sulphates, almost invariably present with sulphites, are of course quite easily separated by filtration and treating with the barium salt in acid solution. Sulphides if present in the solution would seriously interfere with the working of this method if not removed, being readily oxidized by the iodine or bromine to sulphite, sulphate or, should sulphur also separate, to thiosulphate. We found in course of our work that in attempting to neutralize a mixture of freshly prepared alkaline sulphide together with a sulphite we often obtained a precipitate of sulphur. After the removal of the sulphide and sulphate, we were surprised to find on treating with iodine scarcely a trace of sulphite. On treating with bromine however an abundant indication of thiosulphate was obtained. It is well known of course that thiosulphate may be found by boiling a sulphite with sulphur, but that this reaction should take place so readily and completely seemed to us rather unusual.

For the removal of a sulphide before proceeding with the tests for sulphite and thiosulphate Grieg Smith recommends the passing of carbon dioxide through the solution until the escaping gas gives no indication of hydrogen sulphide, but Bloxam* calls attention to the tedious and wholly unsatisfactory character of this method of removal and recommends a mixture of zinc chloride, cadmium chloride, ammonium chloride and ammonia. We have found that the addition of zinc acetate to a faintly alkaline solution accomplishes the same purpose in an entirely satisfactory manner. The sulphide used in our work was freshly made by passing hydrogen sulphide through a dilute solution of sodium hydroxide. When portions of this solution, still alkaline, were treated with zinc acetate in excess, and the zinc hydroxide and sulphide removed by filtration, the filtrate gave no test for either sulphite or thiosulphate by the application of iodine and bromine as described, and the vapor evolved on boiling caused no darkening of lead paper. The following table shows the results of a few experiments in which tests

TABLE V.

K_2SO_3 taken. grm.	$Na_2S_2O_3$ taken. grm.	$BaSO_4$ precipitated after oxidation with iodine.	$BaSO_4$ precipitated after oxidation with bromine.
0·1	0·01	Abundant	Good.
0·1	0·001	Abundant	Distinct.
0·01	0·1	Good	Abundant.
0·001	0·1	Faint	Abundant.
0·001	0·001	Fair	Fair.

* Chem. News, lxxii, 63.

were made for the sulphite and thiosulphate, after removing a considerable amount of the sulphide in the manner described, and of the sulphate by acidifying and adding barium chloride.

The method as we have modified it may be summarized as follows: To about $0{\cdot}1^{grm}$ of the substance to be analyzed dissolved in 10^{cm^3} of water or more, add sodium, potassium or ammonium hydroxide to distinct but faintly alkaline reaction. The solution should be neutral or alkaline rather than even faintly acid, owing to the readiness with which sulphur separates. To the alkaline solution add zinc acetate in distinct excess and filter. The precipitate may be tested for hydrogen sulphide, on acidifying, in the usual manner. To the filtrate add acetic acid, a few drops in excess of the amount necessary to neutralize, and barium chloride, and filter through a double filter. To the filtrate add iodine until the solution takes on a permanent yellow tinge, and then bleach with stannous chloride, best after adding a few drops of hydrochloric acid to prevent the possible precipitation of a basic salt of tin. A precipitate at this point indicates the sulphite. Filter, add bromine water in faint excess to the filtrate, bleaching again with stannous chloride. A precipitate on adding bromine indicates a thiosulphate originally present.

ART. XXXII.—*Twinned Crystals of Zircon from North Carolina;* by W. E. HIDDEN and J. H. PRATT.

THE zircon crystals to be described in this paper were found at the Meredeth Freeman Zircon Mine in Henderson County, North Carolina. The mine is located near Green River and about two miles nearly south from the railroad station now known as Zirconia. This is the mine from which Gen. Thomas Clingman procured one thousand pounds of zircons as early as 1869 and which became later a large producer. The crystals occur in a saprolitic rock that was probably a biotite gneiss.

The attention of one of us was drawn to some peculiar crystals of zircon in May, 1888, by a miner who was then regularly employed in washing out zircons from the rock of this region. This miner stated that some of the men were finding "zircon-crosses" which they were wearing as ornaments, some having them "sewed to the lapels of their coats" and others "using them as watch charms." At first, no serious attention was paid to the miner's statement, for at that time it was impossible to visit the mine and verify it and besides staurolite seemed suggested by this description. Specimens of these "crosses" were received during the same month, but unfortunately they were badly broken in transit.

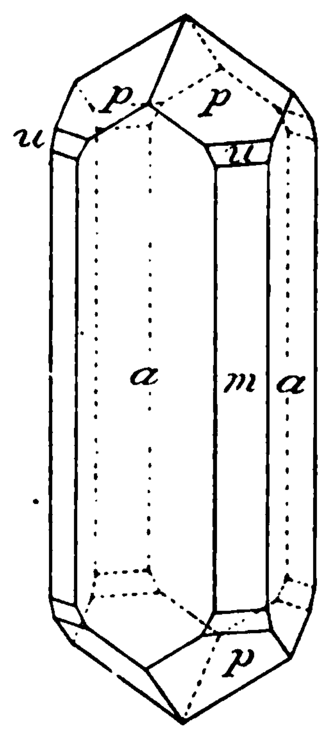
During the following summer the locality was visited by one of us, but all work had ceased at the mines. The dump was carefully searched over for the "zircon-crosses" but without success. The miners, while they well remembered the finding of these crystals, had not saved any specimens of them. The foreman, Mr. Edward H. Freeman, had fortunately preserved a small collection of different crystals found at this mine and it was from this collection that the crystals described in this paper were selected. Mr. Freeman stated that the "zircon-crosses" were obtained from only one portion of the mine and that some were found about 1½ in. long by ⅜ in. thick. He also said that they were very easily broken if carelessly handled.

All the zircon from this region occurs as crystals which vary in size from 1^{mm} to 30^{mm} in the direction of the $\dot{c}$ axis and from 1^{mm} to 25^{mm} in that of the horizontal axes. The color varies from gray to grayish and reddish brown.

The common type is the prism of the first order, *m*, 110, terminated by the unit pyramid of the same order, *p*, 111. A few crystals have been observed with the prism terminated by the steeper pyramid, *u*, 331 alone and also a combination of

this form with the unit pyramid. Rarely the crystals have the ditetragonal pyramid *x*, 311, in combination with the unit pyramid. Fig. 1 represents one of a rarer type of crystals which is a combination of the prisms of both orders, *m*, 110 and *a*, 100, terminated by the unit pyramid, *p*, 111 and the more acute pyramid *u*, 331.

1.



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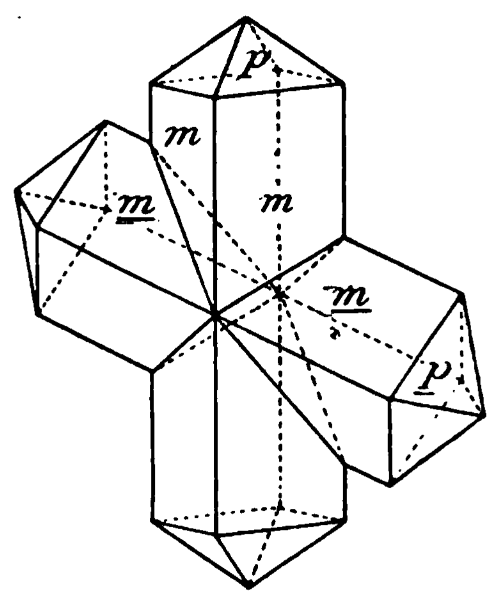
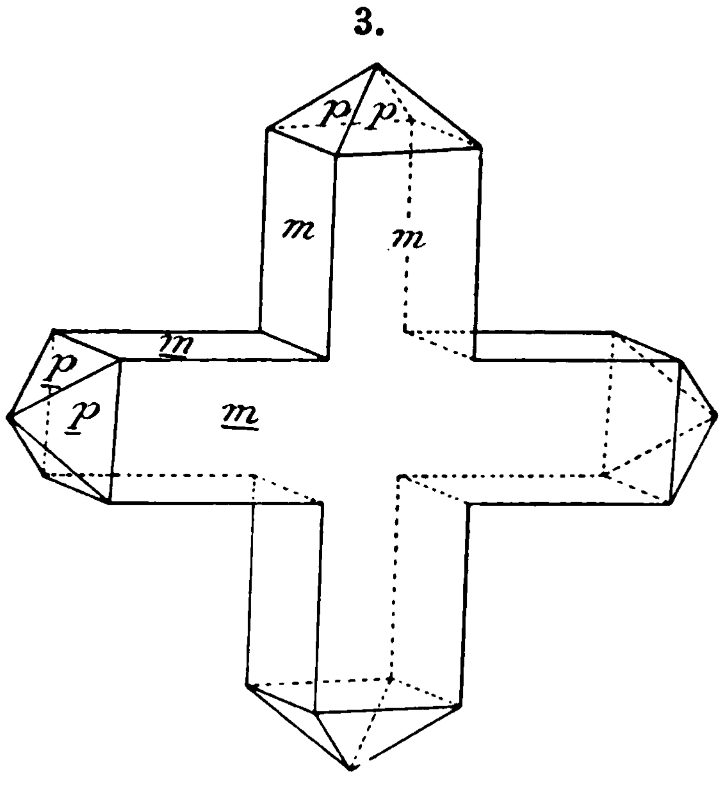


The only type of twinning heretofore known for zircon* is that with *e*, 101 as twinning plane, forming geniculations like those of rutile and cassiterite. The same law of twinning was observed on the Henderson County zircons, but the crystals are cruciform as shown in fig. 2.

3.



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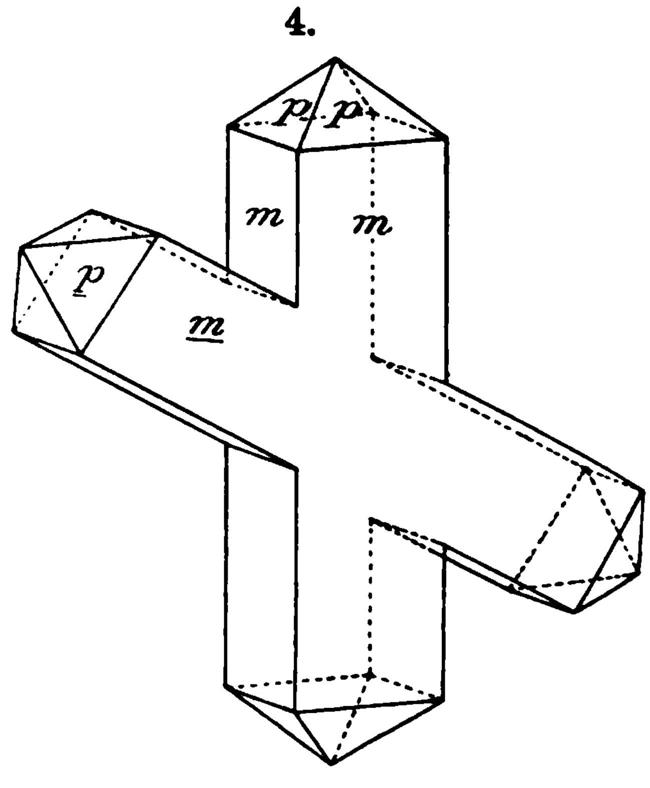
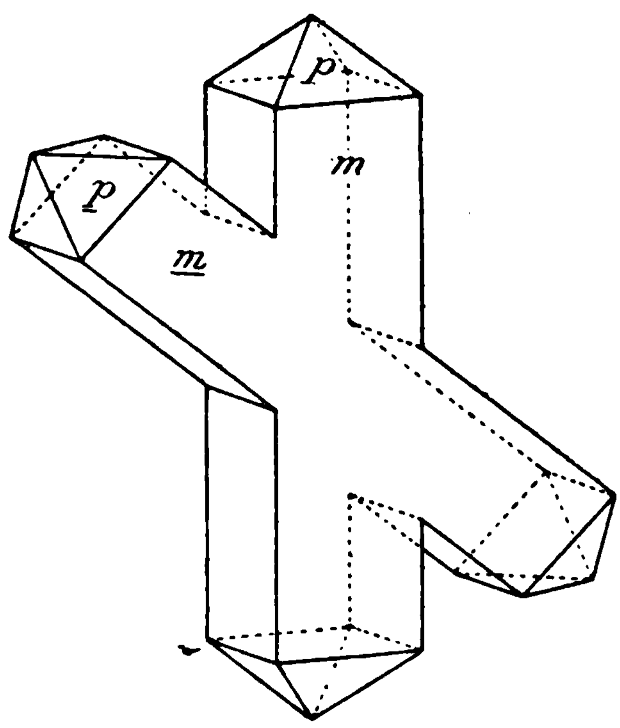


* This Journal, xxi, 507, 1881, Hidden; Phil. Mag., xii, 26, 1881, Fletcher; and Dana's Mineralogy, sixth edition, 1892, p. 486.

Besides this type the Henderson County zircon exhibits a series of twin crystals in which the twinning planes are parallel to pyramids of the first order. Five new twinning planes have been identified by us. Of these, four are parallel to the pyramidal faces, *p*, 111; *d*, 553; *v*, 221 and *u*, 331, and are represented by figs. 3, 4, 5 and 6 respectively; the fifth is parallel to the pyramid ϕ (774).*

The twin crystals are usually well developed and doubly terminated, the faces being somewhat vicinal but with sharp edges, thus enabling the faces and twinning planes to be

5.



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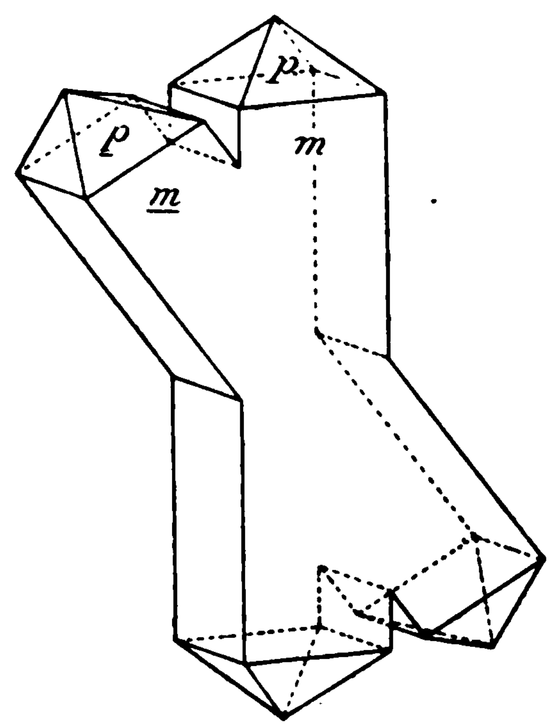


readily identified by means of the contact goniometer. The measurements were very satisfactory and close to the calculated angles, as shown in the following table:

Twinning planes.	Measured angles $m \wedge \underline{m}$.		Calculated angle.
p (111, 1)	95° 10′; 96° 30′ 95°	Average 95° 33′	95° 40′
d (553, $\frac{5}{3}$)	112 10 ; 113 20′; 111 40′	" 112 23	112 50
ϕ (774, $\frac{7}{4}$)	116 30 ; 116 ; 115° 30′; 115° 15′	" 115 49	115 30
v (221, 2)	121 30 ; 122 30	" 122	122 12
u (331, 3)	138 ; 139° 10′; 140 ; 139° 30′	" 139 10	139 35

The re-entrant angle formed by $m \wedge \underline{m}$ over the twinning plane is the same as the angle of divergence of $\dot{c} \wedge \underline{\dot{c}}$. These prismatic edges being very sharp, the re-entrant angle could be measured very accurately with the contact goniometer, the measured angles agreeing within half a degree of the calculated angles.

The minerals associated with the zircon are the following: Pyrite, in cubes partially changed into limonite; fluorite, pale

* Dana's Mineralogy, sixth edition, 1892, p. 482.

purple etched fragments; quartz crystals; ilmenite, in minute grains (rare); small octahedrons of magnetite; orthoclase; massive garnet; parallel growths of auerlite upon unaltered gray and brown zircon; very good crystallized green epidote; allanite in masses, as large as 50 pounds; well crystallized brown sphene, most of the crystals are altered to xanthitane; and vermiculites with broad foliæ often four to six inches in diameter.

The thanks of the writers are due to Mr. Freeman, who generously presented the crystals used in the preparation of this paper.

ART. XXXIII.—*Note on the Brachiopod Fauna of the Quartzitic Pebbles of the Carboniferous Conglomerates of the Narragansett Basin, Rhode Island;* by CHARLES D. WALCOTT.

THE first notice we have of the fossiliferous pebbles of the Carboniferous conglomerates of the Narragansett Basin is by Professor Wm. B. Rogers, who in 1861 announced the discovery by Mr. Norman Easton of pebbles carrying fossils of the Potsdam fauna in the Carboniferous conglomerate north of Fall River, Mass. Professor Rogers thought the forms distinctly recognizable to be Lingula of two species, *L. prima* and *L. antiqua* Emmons.*

In 1875 Professor Rogers announced the discovery of impressions suggestive of the fossil Lingulæ mentioned by him from Fall River in the pebbles in the conglomerate at Newport, Rhode Island.† He thought that the pebbles were derived from rocks probably closely connected in time with the Braintree Paradoxides beds.

During the past two or three years Professor N. S. Shaler and Mr. J. B. Woodworth have been sending me fossiliferous pebbles picked up on the beach on the northern shore of Martha's Vineyard, and at several points along the shore of Narragansett Bay. Among these I find remains of two large Linguloid brachiopods which appear to be identical with *Obolus* (*Lingulobolus*) *affinis* Billings and *O.* (*L.*) *spissus* Billings, from the Lower Ordovician rocks of Great Belle Island of Newfoundland. The material is somewhat imperfect, but in comparing it with the series of specimens from the typical locality in Newfoundland, the two species appear to be present. There is also a new species, which I have named *Obolus* (*Lingulella*) *rogersi*, which occurs both in the quartzitic pebbles in the Narragansett Basin, and with *O.* (*L.*) *affinis* and *O.* (*L.*) *spissus* in Newfoundland.

The geologic horizon of the sandstones on Great Belle Island which carry the brachiopods is not far above the shales carrying an Upper Cambrian fauna. It is quite probable that the horizon represents the passage beds between the Cambrian and Lower Ordovician.

The exact locality from which the quartzitic pebbles of the

* The Fossiliferous Pebbles of the Potsdam and Carboniferous Conglomerate North of Fall River, Mass.; Boston Soc. Nat. Hist. Proc., vol. vii, 1861, pp. 389–391.

† On the Newport Conglomerate; Boston Soc. Nat. Hist. Proc., vol. xviii, 1875, p. 100.

Carboniferous conglomerates were derived is not, and probably will not be known. The fact that Great Belle Island is the only locality at which this peculiar group of brachiopods has been found points strongly to that region as the probable source of the fossiliferous pebbles of the conglomerate. If so, this strengthens the view of Professor Shaler that the conglomerates are of glacial origin, as it is evident that no other means of transportation than the glacier would carry pebbles of the size of those in the conglomerate so great a distance as that from the St. Lawrence Valley to the Narragansett Basin.

No other fossils have been found in the pebbles other than the brachiopods.

ART. XXXIV.—*The Origin and Significance of Spines: A Study in Evolution;* by CHARLES EMERSON BEECHER.

[Continued from page 268.]

VII. *By repetition.* (B_2.)

UNDER the consideration of spine production by repetition, it is proposed to include local repetition or duplication of spines on or about a primary spine, the limit of this repetition resulting in a generally spinose condition.

It has been shown that intermittent stimulus produces growth, and furthermore that growth can only take place with proper nutrition. Under local stimulus, the currents of the circulation or forces of nutrition are set up in an organism toward the center of stimulation. The nutrient matter is brought to this point, and more or less of it is expended in building up a structure which is the reciprocal or direct resultant of the stimulus. Now, since all motion is primarily rhythmic,[66] and the repetition of parts an almost universal character among organisms,[5] it would appear that the foregoing conditions would be favorable to the repetition or reproduction of the structures. In this way, it is easy to account for the growth of spines that cannot be explained as the direct result of external stimuli (A), or by any process of decrescence (C, D). The nature of the influence seems to be similar to induction in electrical physics, or to the force or stimulus of example in human conduct.

Stated as a concrete case, a simple spine produced by any primary cause may be taken, and it will be granted that the vital or physiological adjustments produced in its growth and maintenance have brought about or induced an harmonic condition in the adjacent tissues. Subsequent growth will most naturally repeat the previous structures, so that in addition to the primary spine, there will be other smaller spines on or about it, together constituting either a compound spine or a group of spines.

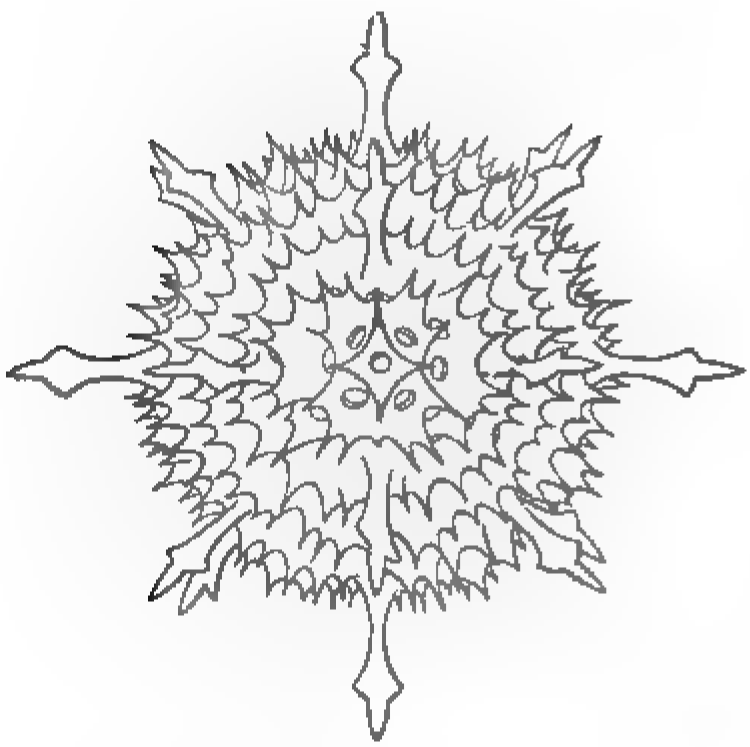
Carrying this repetitionary process to a maximum, there would result a generally spinous condition. As a possible illustration of this, no class of organisms probably exhibits so many kinds and series of repetitions of all sorts of external structures as the Echinodermata, and it is significant that this is a typically spiniferous sub-kingdom.

Except in a few classes of organisms, compound spines are relatively rare as compared with simple spines. They are very common among the Radiolaria, which furnish the greatest complexity occurring anywhere in the organic world. (See Plate

I.) They are also quite frequent among the Echinoidea, but more rare among the Asteroidea and Crinoidea.

Compound antlers are especially characteristic of the modern Deer family, though compound horns are but rarely found elsewhere among the mammals. The Prong-horn Antelope of America is the only living species of hollow-horned ruminant having this character. It, of course, is not intended that extra pairs of horns, which being separate, and often originating on different portions of the skull, should be considered as compound horns in the sense employed here. Likewise compound spines arising through suppression of organs or structures are not to be included here, as the compound thorns on the Honey-locust representing aborted branches.

51.



52.

53

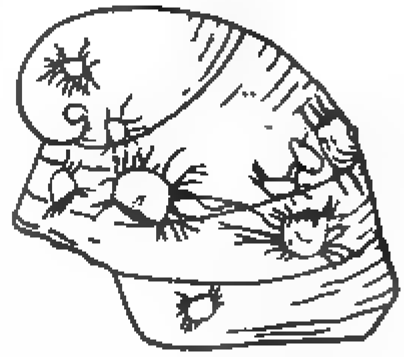


FIGURE 51. *Acontaspis hastata.* A Radiolarian, showing multiplication of spines by repetition. × 200. (After Haeckel.)

FIGURE 52. *Strophalosia keokuk.* An attached Brachiopod, showing the spines extending from the ventral valve to and along the surface of attachment. × 2.

FIGURE 53. A Gastropod shell (*Platyceras*) to which are attached a number of *Strophalosia keokuk* Natural size

The fin-spines of fishes are often compound, and sometimes are made up of several elements as in the spines of *Edestus* (*E. vorax*). Quite a number of Mollusca develop compound spines, as in many species of *Spondylus* and *Murex*. They are also not uncommon among the Crustacea and Insecta. Compound spines are infrequent in the Brachiopoda, being developed in but few species (*Spirifer hirtus*[11]). The Foraminifera also present but few examples (*Polymorphina Orbignii*[6]).

A number of generally or highly spinose types will now be noted to illustrate the limits of the repetition of spiny structures, the first spines having probably arisen through the operation of some primary cause, and the derived or secondary spines being produced, it is believed, by the law of repetition.

The Radiolaria have already been frequently mentioned, but as they are the most spiniferous of all classes of animals, and represent the highest degree of spine differentiation attained (figure 51 and Plate I), another brief notice will be of interest. These spines furnish characters of high taxonomic value, although generally speaking they seldom have more than specific importance among other classes. The Echinoidea and Asteroidea must also be noticed in this connection, though from the nature and origin of their spines, they do not conform to the mode of spine growth in other classes.

Productus, *Productella*, *Strophalosia*, *Aulosteges*, and *Siphonotreta* represent highly spinose genera among the Brachiopoda. *Strophalosia* is a form in which the ventral valve is cemented to some object. Whenever the valve rises well above the object of support, the spines are free like those frequently present on the dorsal valve; otherwise the spines extend root-like along the supporting surface (figures 52, 53). *Aulosteges* presents a still further tendency to complete spinosity, for not only are both valves covered with spines, but the deltidium also.

Spondylus (figure 30) and *Murex* are well-known types of very spiny forms of Mollusca. *Acidaspis*, *Terataspis*, etc., hold the same place among the Trilobita; *Echidnoceras*, *Lithodes*, etc., among the Decapoda; and the Spiny Box-fish (*Diodon*), Pipe-fish, etc., among the Pisces. The higher animals also furnish examples of extreme spinosity, as in the Horned-Toad (*Phrynosoma*), the genera of Ceratopsidæ, gigantic Cretaceous Dinosaurs, and the Echidna and Porcupine.

All these forms present numerous spines, some of which cannot be explained as having arisen directly from external stimuli, for they are in comparatively well-protected regions out of the way of external stimuli. Neither can all of them serve for offense and defense, as they are often not located in the most advantageous positions; nor are they differentiated out of any previous ornaments or special structures. In fact, no factor of spine genesis except the one of repetition seems to be sufficient to account for their development.

VIII. *Restraint of environment causing suppression of structures.* (C_1.)

The previous categories of spine production (I–VII) have been brought about by some process of growth or concrescence

through external and internal agencies. There still remain for discussion the formation of spines by processes of decrescence caused by extrinsic restraint (C), or intrinsic deficiency of growth power (D). The lack of vitality or growth force generally stands so directly as the result of an unfavorable environment, that it is often difficult or impossible to distinguish between their action. Furthermore, as in the case of many parasites, it may be seen that the environment may be quite favorable as regards temperature, nutrition, etc.; but unfavorable in respect to motion and use of sensory and motive organs. From the almost universal degradation and retrogression of parasitic forms, it is necessary to consider these as intrinsically deficient, and therefore lacking in the qualities of growth force which normally favor a progressive evolution. Here, also, there are apparently two intimately associated causes. In an attached animal, the absence of stimulus from disuse of an organ tends toward atrophy, and the retrogressive development serves to affect many organs in the same manner. The direct and indirect results of the restraint of the environment may therefore be expected to shade imperceptibly into each other, with only the extremes sufficiently distinct for separation.

The influence of an unfavorable environment as effecting the character and growth of plants and animals is well shown in desert or arid regions, and the flora has been made the subject of especial study by Henslow.[33] In such regions, the first thing to impress the observer is the small size of the species. Next to diminutive size, the scantiness of life is a striking feature, for large areas are common in which life is almost wanting. An examination of these plants reveals a series of characters not usually present elsewhere, among which may be mentioned the development of a minimum amount of surface, constituting what is known as consolidated vegetation; next their uniform gray color, due either to excessive hairiness or a coating of wax; and lastly, their frequent spinescent characters.

The spines on desert plants are a feature of such general occurrence that it has led to the notion that vegetable spines are always associated with unfavorable conditions and are therefore suppressed structures. This is probably incorrect, for in plants as in animals, spines may be developed by the progressive differentiation of previous structures; as in the angular edges of the leaf-stems of many Palms becoming spiniferous; or, as will be shown, suppressed structures may arise from deficiency of growth force. In all cases, spines may or may not serve for protection. Thus, while they are not always an indication of unfavorable environment, those occurring on desert plants may generally be so considered, for they are

developed out of structures which are normally of vital physiological importance.

An animal or plant having spines and living in a favorable environment, involving freedom of motion for animals, and abundance of nutrition without extremes of temperature or dryness for both animals and plants, will, it is believed from the discussions and analyses of spine genesis in its various phases, develop these features in most instances, without the sacrifice of organs and structures having important physiological and motor functions. Thus, ordinarily, among animals it is found that spines arise as excrescences or outgrowths of exoskeletal or epidermal tissues, without seriously affecting the function of the organ or organs upon which they are located. Such cases may clearly belong to the most progressive series, and in fact usually occur there.

On the other hand, if it is found that a leg, a wing, a digit, or other organ is developed into a spine, this is always accomplished by a process of retrogression, resulting in the greater or lesser suppression of the part in question. It is also seen that this kind of spine occurs most frequently in retrogressive series or in others showing arrested development, and the necessary interpretation seems to be either that the environment is or has been unfavorable, at least so far as the particular organ or set of organs is concerned, or that the vital power has declined. Both influences are intimately associated, and the latter is often the direct result of the former.

The stunting effects of aridity and barren soil on our common plants is familiar to all. Among the plants of the desert is found every evidence of similar stunting combined with adaptations to resist the unfavorable conditions of deficient water supply, excess of radiation, etc. The diminution in size applies not only to stature, but to the leaves and branches, especially the parenchymatous tissues or parts of the plant engaged in aëreal assimilation. Consonant with these changes, the drought and other conditions produce a hardening of the mechanical tissues, which is of great aid in resisting the extreme heat and dryness of the desert. Sometimes a deposit of wax affords a similar protection.

The reduction of the leaves takes place in various ways. They may simply become smaller in every dimension and finally be reduced to mere scales, or an aphyllous condition may be established. They may grow narrower and narrower until only the hardened veins or midrib remains; or leaves may be developed only for a short time, and, in the case of compound leaves, after the shedding of the leaflets, a spiniform leaf axis remains, as in *Astragalus Tragacantha*[35] (figures 55, 56). The suppression of branches tends towards the same end;

namely, either to their complete disappearance or to their partial suppression into hard spiniform processes or thorns. Thus, both leaves, branches, and other parts of the plants may become reduced to their axial elements, bringing about what is commonly termed spinescence.

The spiny character of these plants is therefore one of the results of an arid environment, and it may or may not be of sufficient frequency to give an especial character to a particular desert flora. There is, moreover, a secondary influence which has an effect in determining the abundance of spinose plants in desert as well as in many other situations. This relates to the destruction of the edible unarmed species by herbivorous animals, and the comparative immunity of the spiny types. Thus, in old pastures, the prevailing flora is apt to be one that is offensive to grazing animals. This character is generally given by poisonous plants or those having a disagreeable flavor, or by those whose form or spiny structures afford protection.

This secondary influence by grazing animals may have had some effect in determining the particular abundance of spiny plants in certain desert regions, and their comparative infrequency in other similar regions. In either case, the unfavorable environment brings about a suppression of structures, and one type of this action results in the production of spines. These represent the limits of retrogression before the part becomes entirely obsolete.

Wallace has criticised Henslow's views on the origin of xerophilous plants and their distribution. It is believed that the views here offered remove some of the objections, and bring the opinions of these authors into greater accord.

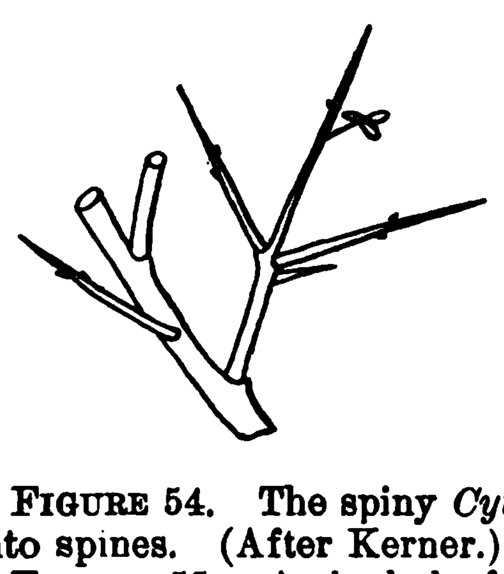
Under arid conditions, bracts, stipules, leaves, and even branches may become spinescent. Some forms in which the spinose character has not as yet become permanently fixed by heredity, when transported or found living in moister and richer soils, develop normal leaves or branches, and lose their spinescence; others, like the Cactus, retain their spines under similar changes; while still others, as *Acanthosicyos horrida*,[33] cannot be artificially cultivated, and have become truly xlerophilous types.

As examples of plants which lose their spines by cultivation, the Pear, species of Rose, Plum, etc. (Henslow), may be cited. According to Henslow,[33] others, as *Onomis spinosa*, have an especially spiny variety (*horrida*) living on sandy sea-shores, while in more favorable natural situations, the same plant becomes much less spiny, and under cultivation loses its spines. M. Lothelier[42] also found that by growing the Barberry (*Berberis vulgaris*) in moist air, the spines disappeared, the parenchyma of the leaves being well formed between the ribs and

veins. Dry atmosphere and intense light both favored the production of spines.

Henslow[33] cites the genus *Zilla* as a desert plant in which the branches are transformed into spines, *Echinops* for a similar modification of the foliage, *Fagonia* for spiniform stipules, and *Centaurea* for spinescent bracts. As further illustrations taken not only from desert plants but also from others commonly found in dry, rocky, or unfertile situations, the following examples may be taken, some of which are familiar cultivated species. The stunting of branches into spines is common among neglected Pear and Plum trees, and is a normal character in the Hawthorn, Honey-locust, *Cytisus* (figure 54), *Vella*, etc. Leaves transformed into spines are characteristic of the Cactaceæ of America, the columnar Euphorbiaceæ of Africa and southern Asia, and are also familiar in the half-shrubby Tragacanth bushes (figures 55, 56) so common in southern Europe, especially in the eastern portion, and in the ordinary Barberry (figure 13). Spiniform stipules are usually present in the species of *Robinia*, of which the Common Locust (*Robinia pseudacacia*) furnishes a well-known illustration (figure 57). Spiniform bracts are best known among the Thistles (*Cirsium lanceolatum*, *C. horridulum*, etc.).

54.



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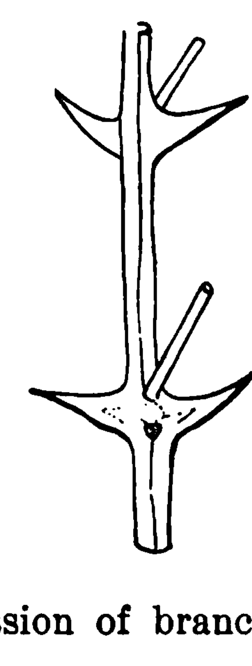

FIGURE 54. The spiny *Cytisus* (*C. spinosus*), showing suppression of branches into spines. (After Kerner.)

FIGURE 55. A single leaf of Tragacanth (*Astragalus Tragacantha*) from which the three upper leaflets have fallen. (After Kerner.)

FIGURE 56. Leaf axis of the same, from which all the leaflets have fallen. (After Kerner.)

FIGURE 57. Twig of Common Locust (*Robinia pseudacacia*), showing spines representing stipules.

As the restraint of an environment acting on an animal so generally results in the disuse and atrophy of the organs affected, most cases will have to be considered under the head of disuse. Therefore, while the environment is the primary factor, its influences are mainly exhibited through secondary or resultant conditions. In some cases, however, it is possible

to interpret a vestigial or suppressed structure directly into terms of an unfavorable environment. Thus, if the probable origin of the vestigial hind legs of a Python is considered, it leads to the belief that they represent legs which were of functional importance to some of the early ancestors of this snake. The gradual elongation of the body and the consequent change from a walking or direct crawling habit to a mode of progression chiefly by horizontal undulations, necessarily brought the legs into a relation with the environment which was unfavorable either for their function or growth. Their suppression is complete in most snakes, but in the Python, the hind legs are represented by two spurs or spines (figure 58). On the interior of the body they are supported by vestiges of femora and ilia, showing their true affinities with hind limbs. Some snake-like Batrachians (as *Amphiuma* and *Proteus*) still retain short and weak external limbs. These would undoubtedly soon be lost by a change from aquatic to terrestrial or arboreal habits.

58.

59.

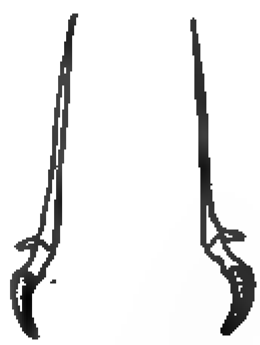

FIGURE 58. Portion of skin of Python, showing the spurs which represent the suppressed or vestigial hind legs. $\times \frac{1}{2}$. (After Romanes.)

FIGURE 59. Bones of suppressed legs of Python. All but the claw-like termination are internal. $\times \frac{1}{2}$. (After Romanes.)

In explanation of the nodes and spiniform processes on the epitheca of *Michelinia favosa*, it may be suggested that they represent aborted corallites, or attempts at budding. This coral belongs to the order Porifera, which has been shown by the writer[1] to have very pronounced tendencies toward proliferation, and on the interior of the colony, these attempts result in the production of mural pores. Most of the species of *Michelinia* are hemispherical or spherical. *M. favosa* is inclined to be pyriform in shape, rising above the object of support, and thus presenting a rather large epithecal surface. Manifestly the lower side of the corallum is unfavorably situated for the growth of corallites, and any efforts at proliferation on the part of the peripheral corallites is apt to result in stunted outgrowths. There is here a very close connection

between restraint of environment and deficiency of growth force. If the whole corallum is taken into consideration, the restraint of the environment may be taken as preventing the growth of corallites on the lower side. If one of these single stunted corallites is considered, it may be said that the deficiency of growth force through lack of nutrition caused its suppression.

IX. *Mechanical restraint.* (C_2.)

Among the factors of spine genesis, mechanical restraint is probably of the least importance. It can only rarely happen that an organism is forced to grow a spine contrary to the natural tendencies of normal development. Yet as there are occasional types of spiniform structures which can best be explained as due to the mechanical restraint of the environment, it is necessary to notice them in order to make the categories of origin as complete as possible.

The illustrations will be taken chiefly from the Brachiopoda and Trilobita. The recent Brachiopod *Mühlfeldtia truncata* is semi-elliptical in outline, and has a very short stout pedicle which holds the shell so closely to the object of support that the beak is truncated from abrasion and resorption. In specimens attached to a small branch of a coral, thus allowing the cardinal extremities of the shell to project beyond the object of support, the ends of the hinge are generally rounded. Specimens growing on a large flat surface have the cardinal extremities angular or submucronate. Similar variations are to be observed in other living species of Brachiopods (*Cistella*, some *Dallina*, etc.). Some of the extinct genera show more highly developed cardinal extremities which are often very characteristic of certain species, though considerable variation is found to exist. It is evident that these elongated hinge lines have arisen from the mechanical necessities of a functional hinge, and their greater or less extent is also to a degree dependent upon the nature of the object of support which furnishes a stimulus to the growing ends of the hinge. A marked example is shown in *Spirifer mucronatus*, with the cardinal angles extended into spiniform processes (figure 60). Similar features are presented by many other species of *Spirifer*, *Orthis*, *Leptæna*, *Stropheodonta*, etc.

60.

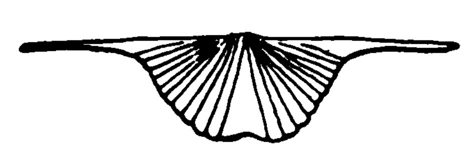

FIGURE 60. Dorsal view of *Spirifer mucronatus*, Devonian. Showing spiniform cardinal angles. × $\frac{2}{3}$. (After Hall and Clarke.)

In the Trilobites, the pygidium, or abdominal portion, consists of a number of consolidated segments, and the segments of the thorax are successively added in front of this tail piece. The first thoracic segment is therefore formed between

the cephalon and pygidium, and its form is mechanically in agreement with the requirements of the animal for bending the body, and with the adjacent margins of the cephalon and pygidium. In a way, it may be said that the segment is moulded by the adjacent parts, and may therefore take its form from the cephalon (figure 61), or from the pygidium, as in the examples following:

61 62 63

64 65

FIGURE 61. *Illænus* (*Octillænus*) *Hisingeri*, Ordovician, Bohemia. A Trilobite showing spiniform pleural extremities of first thoracic segment, corresponding to the genal spines of the cephalon. × ½. (After Barrande[4].)

FIGURE 62. *Cheirurus insignis*, Silurian, Bohemia. Pygidium and six thoracic segments. × ½. (After Barrande.)

FIGURE 63. *Deiphon Forbesi*, Silurian, Bohemia. Entire specimen showing spiniform pleural of segments corresponding in direction to those of the pygidium. (After Barrande.)

FIGURE 64. *Lichas scabra*, Silurian, Bohemia. Pygidium with three thoracic segments, showing spiniform ends of pleura. × ½. (After Barrande.)

FIGURE 65. *Paradoxides spinosus*, Cambrian, Bohemia. Pygidium and six free segments. × ½. (After Barrande.)

During growth, the new segments are added in front of the anal segment, so that after the number of abdominal segments is complete the thorax is increased by the successive addition of what in earlier moults were pygidial segments. By this means, the pygidium generally controls or determines the character of the segments of the thorax. If the pleura of the pygidium are extended into spiniform processes, the pleural ends of the segments are also spiniform, as in *Lichas* (figure 64), *Ceraurus*, *Cheirurus* (figure 62), *Deiphon* (figure 63), *Acidaspis*, *Dindymene*, etc.

Likewise, if the pleura or their distal ends are directed posteriorly nearly parallel to the axis, the mechanical necessities of motion require that the portions of the free segments pointing backward should be free, thus making the ends of the thoracic pleura generally appear as retrally curved spiniform extensions. Extreme examples of retrally directed pleura accompanied by small pygidia are shown in *Paradoxides* (figure 65), *Holmia*, *Olenellus*, *Elliptocephala*, etc. Genera having the ends only of the pleura directed backward are generally less inclined to form spiniform terminations. In contrast with these, it is found that all the Trilobites having the pleura directed outwards and with entire pygidial margins, do not ordinarily develop long pleural spines; as *Asaphus*, *Illænus*, *Agnostus*, *Phacops*, *Calymene*, etc.

The examples of the caterpillars of moths belonging to the Schizuræ, described by Packard[64] as mimicking the serrations of the leaves upon which they feed, have previously been noticed in this essay, under the head of mimetic influences. The initial cause of the spines may possibly be explained as in part due to the mechanical conditions. During their early existence the larvæ feed on the lower side of the leaves, and have no spines. Later they feed on the edges of the leaves, and at the same time acquire dorsal spines. The conformation of the animal to the serrated edge of the leaf would produce corresponding elevations and depressions on the back. The location of these would be fairly constant from the habit of the animal of feeding chiefly between the denser leaf veins which determine and terminate the serrations. The raised parts of the animal would receive the greatest amount of stimuli, and at these points spines would naturally appear.

The processes producing the spines noticed in this category (IX) are classed with others under decrescence, for the reason that the growth is restrained or controlled by mechanical necessities. If the restraint were absent, it is probable that a more expansive growth would take place or that other structures would be correspondingly benefited.

X. *Disuse.* (C_3, D_2).

In causing the reduction or atrophy of an organ, the effects of disuse have generally been recognized by most observers. In this way, the origin of many of the so-called "rudimentary organs" has been satisfactorily explained by Darwin[14] and others. Two classes of structures are evidently comprised within the common definition of rudimentary organs, namely, nascent and vestigial organs.

Nascent structures indicate the beginnings or initial stages

of organs, while vestigial structures are the remnants left after the functional suppression of organs. The suppression is usually caused by unfavorable conditions or by disuse, which produce either a retardation of growth or a retrogressive development. In both cases, the results are similar. By retardation, an organ is prevented or restrained from functional development and is therefore useless as a normal organ. By retrogression, an organ gradually reverts to an initial type, loses its function, and becomes a vestigial structure. In most instances, a change of food or habit, or the substitution of a new and functionally higher structure, causes the disuse of some organ, which, under previous conditions, was of use to the animal.

Nascent structures, or the beginnings of organs, are generally made up of active tissues that only require stimulus and nutrition to perfect their function. On the other hand, suppressed or vestigial structures are composed of comparatively inert tissue and are in consequence largely made of the mechanical elements of secretion of the organism. It may therefore be considered that true rudimentary or nascent organs are potentially active, and suppressed structures are inert. It is with the latter class, the inert, that a study of spine genesis by atrophy is chiefly concerned.

The gradual loss of function through disuse, and the consequent loss of nutrition with the concomitant rapid decrescence of active tissues, brings about a change in the ratio of active and inert structures. The progression of this process naturally results in the production of a structure having a maximum of inert or mechanical tissues, and a minimum of active constituents. Moreover, it has already been shown that the axial elements are the most persistent, and therefore the last to disappear; also that the peripheral appendages and outgrowths of any organ first show the action of decrescence. Evidently, the conditions here described are favorable for the production of spines out of an organ primarily possessing distinct active functions. The axis of an organ gives the necessary form, and the hard tissue the structure, so that the whole will conform to the definition of a spine given early in this paper; namely, a stiff, sharp-pointed process.

The restraint of the environment was found to be one cause for decrescence of organs. Another, which is properly the subject matter of the present section, is disuse; and lastly, it will be seen how the deficiency of growth force may bring a similar suppression of structures.

There is considerable difficulty in selecting particular examples which will conform clearly to the strict requirements of these three categories. In a certain sense, some of the exam-

ples of spines produced by decrescence may belong to more than one category. However it does not prevent the acceptance of any one of the three as primary causes. Thus, it may be urged that disuse has caused the atrophy of leaves into spines among many desert plants, or produced a similar reduction of the limbs in a Python. While this may be true from one point of view, yet the manifest unfavorableness of the evironment in both, seems to be a sufficient reason for making it the primary factor. On the other hand, many parasites showing similar atrophies are not dependent upon a large number of active organs for their food and maintenance. After finding a host, an abundance of food is at hand, and the environment may be considered a favorable one. All the organs, except those of nutrition and reproduction, then become more or less useless and dwindle away, leaving vestigial organs, or disappearing altogether. Furthermore, a change of habit, as from climbing to flying, will necessarily cause the atrophy of some of the structures used for climbing, and the hypertrophy of others for flying.

Most of the examples illustrating the production of a spine through the atrophy of an organ by disuse are to be found in the legs and digits of animals. The process bears considerable resemblance to the formation of spines on many plants by the suppression of leaves, branches, etc. They will be noticed here, although properly these vestigial structures among animals are more strictly of the nature of claws, or at the most, spurs.

Many parasitic plants, especially among the Balanophoreæ, are reduced to a simple stem bearing the inflorescence. The leaves are represented by scales which are often spiniform, though seldom of sufficient stiffness to entitle them to be called spines. In desert plants, many of which have a similar type of growth, the hardening of the mechanical tissues by the effects of drought has converted similar leaf structures into spines, while the parasitic plants are not normally subjected to such continuous dryness and extreme heat, and therefore the mechanical tissues seldom become hardened.

Parasitic animals, especially among the Crustacea and insects, often show a reduction in the number of joints in the legs, and even in the number of limbs themselves. The terminal claws generally persist, and are sometimes longer than the rest of the leg; as in the Itch mite, *Sarcoptes Scabei*, and in the female of the parasitic Copepod *Lernæascus nematoxys* (figure 66).

Among many aquatic Crustacea and Limuloids, the specialization and seggregation of the ambulatory and swimming appendages towards the head or anterior regions of the body have

produced a corresponding suppression of appendages on or near the extremity of the abdomen. This statement of fact is the basis of the principle of cephalization of Dana,[12] who applies it especially to the Crustacea, as follows: "There is in general, with the rising grade, an abbreviation relatively of the abdomen, an abbreviation also of the cephalothorax and of the antennæ and other cephalic organs, and a compacting of the structure before and behind; a change in the abdomen from an organ of great size and power and chief reliance in locomotion, to one of diminutive size, and no locomotive power." Audouin's law that among the Articulata, one part is developed at the expense of another, may be also noticed here as affording a further explanation of the suppression of the posterior appendages correlative with the greater development of the parts anterior to them. In a Crustacean using its tail for propulsion, as the Lobster (*Homarus*), the telson is broad and flat, and the adjacent segment has a similar development of the appendages. In other forms, as the Horse-Shoe Crab (*Limulus*) and the Phyllocarids, the tail is not used for propulsion, and at best serves chiefly as a rudder, while some of the legs on the anterior part of the abdomen or on the thorax are large and strong and are often provided with paddles. These groups, the Limuloids and Phyllocarids, show a greater or less suppression of the last abdominal appendages, and in many genera, the body terminates in a spiniform telson or tail spine. The process of suppression may or may not result in a spine. In the crabs, the abbreviated abdomen is folded under the cephalothorax, and in *Lepidurus* and *Pterygotus* the telson is a scale or plate-like organ. For the most part, however, the abbreviation of the abdomen and the suppression of its appendages have reduced the telson to a spine, as in *Limulus* (figure 67), *Eurypterus*, *Stylonurus*, and *Prestwichia* among Limuloids; and *Olenellus* among the Trilobites. In addition to a telson spine, the Phyllocarids have two lateral spiniform cercopods, the three spines together constituting the post-abdomen, as in *Ceratiocaris*, *Echinocaris* (figure 68), *Mesothyra*, etc.

Although the last abdominal segments of the Horse-Shoe Crab have lost their appendages and show evidences of suppression, yet the tail spine is a large and useful organ, for it is of just the proper length to enable the animal to right itself after being overturned, which it is unable to do with its feet alone. The process of natural selection has doubtless in this way contributed to the development and retention of the long spine. This use cannot be ascribed to the tail spines of the Phyllocarids, though they evidently were important aids in directing movement, and also offered some degree of protection.

The terminal claws on the phalanges of the wings of some

birds are nearly all that remains of the external fingers, or digits. In the Hoactzin of South America (*Opisthocomus cristatus*), the young bird has a thumb and index finger, both provided with claws, and climbs about much like a quadruped, using its feet, fingered wings, and beak. According to Lucas,[43] a rapid change "takes place in the fore limb during the growth of the bird, by which the hand of the nestling, with its well-developed, well-clawed fingers, becomes the clawless wing of the old bird with its abortive outer finger." Similar claws or spurs occur on a number of other birds, some having functional wings, as in the example just described, and others having only vestiges of wings, as in the Wingless Bird of New Zealand (*Apteryx*, figure 69).

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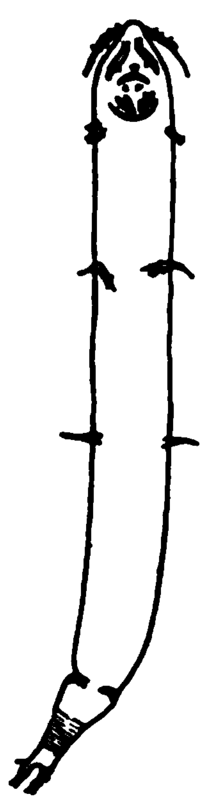

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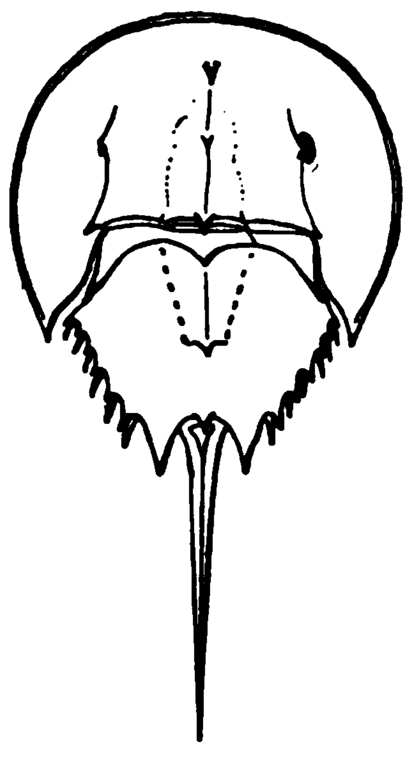

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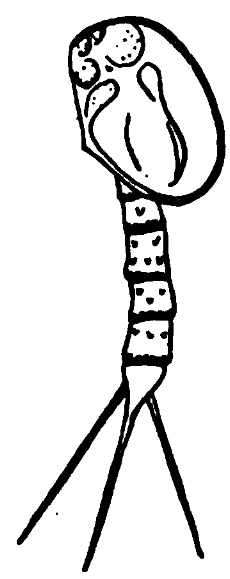

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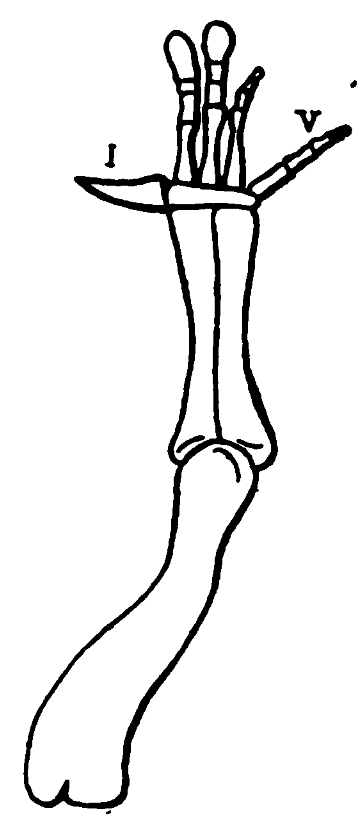

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FIGURE 66. Female of *Lernæascus nematoxys*. A parasitic Copepod, showing suppression of limbs. Enlarged. (After Claus.)

FIGURE 67. Horse-Shoe Crab, *Limulus polyphemus*, showing telson spine and abbreviated abdomen. Reduced.

FIGURE 68. A Devonian Phyllocarid, *Echinocaris socialis*, showing spiniform telson and cercopods.

FIGURE 69. Wing of *Apteryx australis*. $\times \frac{1}{3}$. (After Romanes.)

FIGURE 70. Skeleton of right fore limb of the Jurassic Dinosaur, *Iguanodon bernissartensis*, showing suppressed first digit. $\times \frac{1}{30}$. (After Dollo.[16])

Another example may be taken from the Dinosaurian Reptiles. The Jurassic genus *Iguanodon*, from England and Belgium, belongs to a group (Ornithopoda) in which the number of functional digits varies from three to five in the manus, and from three to four in the hind feet. In this genus, the hind foot had three functional toes, representing the second, third, and fourth of a normal pentadactyl foot. The first is represented by a slender tarsal bone alone, while the fifth is completely suppressed. The manus, or fore foot, of this ani-

mal shows the second, third, fourth, and fifth digits of functional importance as digits, while the first is shortened and atrophied to the condition of a stout spur, standing out at right angles to the axis of the leg, as shown in figure 70. The fore legs of *Iguanodon* and others of the same order were short, and apparently used more for prehension than locomotion, and in *Iguanodon*, the suppression of the pollex, or thumb, into a spur doubtless provided the animal with a powerful weapon. Here is seen the suppression of a digit by loss of normal function, resulting in a protective structure of considerable value.

XI. *Intrinsic suppression of structures and functions.* (D_1.)

The most obvious and direct relationship between an unfavorable environment and the suppression of structures to form spines was afforded by desert plants. In illustration of the intrinsic suppression of structures by deficiency of growth force, the vegetable kingdom again seems to offer the clearest evidences of a like relation between cause and effect. Instead, however, of taking an unfavorable environment, in the present instance a favorable environment must be assumed, and then a type which expresses in various ways its deficiency of growth force must be sought.

In the desert plants, it was found that no single family exclusively constituted the desert flora, but that a considerable variety of types were present, and that some of these belonged to perfectly normal families commonly living under ordinary favorable conditions. Moreover, it was evident that there were certain types of form and habits of growth which were especially characteristic of plants living in desert or similar unfavorable regions. Therefore, to illustrate clearly intrinsic restraint or suppression of structures, it will be necessary to take an environment which, in most respects, may be considered as favorable, and also a type of plant life presenting evidences of a deficiency of growth force.

The great groups of plants commonly known as brambles and climbing plants appear to meet most of the requirements. They abound in regions where the greatest luxuriance of vegetation is found, and are therefore chiefly characteristic of the tropics. Kerner[38] estimates that there are two thousand species of the true climbing plants in the torrid zone, and about two hundred in temperate regions. Tropical America has the largest number of species, the flora of Brazil and the Antilles being especially rich. In the sombre depths of the tropical forest, the climbing plants, or "lianes," are not so abundant as in the open glades and along the edge of the forest, where the amount of light is greater and the conditions of

existence more favorable. As far as richness of soil, amount of light, and degree of temperature are concerned, it must be admitted that their environment is as favorable as that of any of the associated plants having different habits of growth. The difference between the strong and erect plants and the comparatively weak and climbing forms is therefore not an extraneous one. It resides within the plant structures themselves, and is an intrinsic character or an expression of hereditary vital forces.

The law of recapitulation demands that each individual during its development shall pass through an epitome or recapitulation of its ancestral history. In view of the fact that the young seedlings of climbing plants and brambles have the erect form and proportions of normal erect foliage stems, it is safe to infer that they have been derived from erect forms. Further evidence is afforded from the absence of climbing plants in the earlier terrestrial floras. It is obvious, therefore, that they have been developed out of erect forms by a process of degradation.

The next striking feature to be noticed in climbing plants is their extreme slenderness, due to the general suppression of the plant body. They may attain lengths not reached by the highest trees, and yet the diameter of the trunk is but a minute fraction of the length. The Climbing Palm, or Ratan, has stems of great length and tenuity. It has been stated that stems two hundred meters long have been observed having a uniform thickness of only from two to four centimeters.[38] The diameter of such a stem would be only one or two ten-thousandths of its length. The length of the internodes is another conspicuous character in climbing plants, and both this and the slenderness of the stems suggest the results obtained by growing ordinary plants in the dark, where the conditions are adverse to increased vitality.

The transfer of function from one part of the plant to another, usually by a process of retrogression or degradation, is also very common. The first growth above the ground is a leafy stalk. Later, after the plant has attained a considerable height, the lower portion puts out quantities of rootlets and loses its foliage. The rootlets may be mere dry threads or points of support for the stem ; or, if they happen to encounter a crevice containing soil, they develop into true absorbent organs. In others, the ends of the growing stems or any point on the stems, upon reaching the earth, may put out vigorous roots. These facts seem to show a lack of positive differentiation throughout the plant, which admits of the substitution of a lower structure for a higher, by the suppression of a higher function.

Lastly, the general spininess of climbing plants and brambles is a well-known and conspicuous character. Kerner[38] says that "most, if not all, plants which weave into the thicket of other plants are equipped with barbed spines, prickles and bristles." These spiniform processes seem to fall naturally into two classes. First, those produced by the suppression of stipules, leaves, petioles, branches, etc., and second, those appearing as simple eruptions on the surface.

71

72

73

FIGURE 71. Leaf of Ratan, *Dæmonorops hygrophilus*. Reduced. (After Kerner.)
FIGURE 72. Leaf of Ratan, *Desmoncus polyacanthus*. Reduced. (After Kerner.)
FIGURE 73. Bramble, *Rubus squarrosus*. Reduced. (After Kerner.)

The suppression of normal plant organs into special structures, as tendrils and claspers, is extremely common, and, as already shown, this process if carried far enough without complete suppression will favor the production of a spiniform growth representing the axial elements of the organs. The classes of organs thus affected are practically the same as those in desert plants, though varying somewhat in manner and degree. The consolidated type of plant body is naturally absent, for, in this respect, the diffuseness of climbing plants is quite antithetical. It does not seem necessary to give a long list of examples among the climbers, illustrating the suppression of organs into spines. Although apparently not of rare occurrence, spines produced in this way are not as common as among desert plants. Two figures of the pinnate leaves of Ratan are introduced here to show the suppression of a number of the

terminal leaflets into spines (figures 71, 72). In *Machærium* the stipules are converted into thorns.[62] A tropical *Bigonia* (*B. argyro-violacea*) has normal full-sized simple leaves, and suppressed leaves bearing two opposite leaflets on one stalk, and ending "in a structure which divides into three limbs, with pointed hooked claws, and which is not unlike the foot of a bird of prey."[38]

By far the greater number of spines on climbing plants are of the nature of prickles, and are not produced by the suppression of any particular organ or organs, but appear usually without any very definite order. They represent outgrowths of the superficial layers, and hypertrophied plant hairs, or trichomes. The cause of these cortical eruptions is not clear, although they seem to be intimately connected with the general suppression of the plant body. They are therefore a secondary and not a direct result of suppression. Bailey[3] asserts that, "probably the greater number of spinous processes will be found to be the *residua* following the contraction of the plant body." This connection is very apparent in the consideration of the suppression or contraction of various plant organs, but is less obvious when applied to the surface of the whole plant, though doubtless it is the true explanation. In continuation of this idea, it may be suggested that the prickles represent aborted attempts on the part of the plant, through hereditary influences, to recover its former normal proportions. Or, they may exhibit the action of the law of repetition acting in an organism where the initial cause of spine production is the intrinsic suppression of such structures as leaves, petioles, stipules, etc. The subsequent repetition of spines on other parts of the organism results in a series of homoplastic spines which are not homologous with those first formed.

The prickles on climbing plants and brambles may often serve for purposes of protection (D_3), and enable the plant to cling to a support, but these utilitarian properties cannot be considered as an initial cause. Natural selection, also, probably has fostered the development of certain types of spiny climbers and the production of adaptive characters. Nevertheless, in studying these forms, it is necessary to revert to the original consideration of the localized suppression of normal plant structures, and to the general suppression of the plant body as affording a more primary conception of the causes and modes of spine growth among climbing plants.

In many cases of retrogressive series of animals, there seems to be a close parallelism with some of the characters observed among the climbing plants. If the Ammonite family during the Cretaceous, or near the close of the Mesozoic, is taken as an example, it cannot be said that the environment of these old

age or pathologic series is unfavorable in respect to food temperature, etc., for with them are associated many vigorous progressive series of other organisms. Neither can it be said, that in many cases the animals perished on account of over-specialization, though this was evidently the cause of the extinction of a large number. The return to a condition of second childhood in old age cannot be called a progressive specialization, since it clearly points to a deficiency of growth force.

Old age types, or phylogerontic forms, among animals may show the same attenuation or suppression of the body as do climbing plants. Thus, *Baculites*, considered by Hyatt as a typical phylogerontic type, has a very attenuate shell, and some species, after attaining a certain diameter, cease to increase in any direction except length. On account of being a chambered shell, it is manifest that the growth of the animal must have practically ceased, while its secretive activities were continued and confined largely to lengthening the shell. Other related genera of Cephalopods show a similar attenuation of the shell, evincing a stoppage of growth in the animal. Among the Mollusca, it seems quite likely that attenuation of form often accompanies decreased growth power.

The pathologic varieties of the Steinheim *Planorbis*, as described by Hyatt,[35] or of the recent *Planorbis complanatus* described by Piré,[57] are further illustrations of this attenuation accompanying the uncoiling of the shell. The sedentary *Magilus*, immersed in its coral host, is also an example, for not only does the shell cease to increase in diameter, but the whole interior, except a small cavity at the end, is filled with a solid deposit of lime. Similar examples could be multiplied indefinitely. Since, however, but few of them are spiniferous, their consideration does not properly come within the scope of the present discussion, though, as is well known, some of the attenuate forms often enlarge and contract periodically, such enlargements frequently leaving prominent laminæ or nodes that are sometimes differentiated into spines. They suggest the observations on growth, senescence, and rejuvenation, made by Minot,[48] who showed that in guinea pigs from a very early age, the increments of growth are in a steadily decreasing ratio to the increase of weight of the animal. This led to the general conclusion, that the whole life of an individual is a process of senescence or growing old.

Spines arising by a real pathologic or diseased condition of the individual can have little or no effect in producing a normal spiniferous variety or species. However, some note should be taken of them, especially as they may be congenital, and thus appear through several generations. In the human species, the

peculiar skin-disease known as ichthyosis sometimes produces spiniform excrescences, and the victims are commonly called "porcupine-men." The most celebrated instance was the Lambert family. Haeckel[27] gives the following account of this family: "Edward Lambert, born in 1707, was remarkable for a most unusual and monstrous formation of the skin. His whole body was covered with a horny substance, about an inch thick, which rose in the form of numerous thorn-shaped and scale-like processes, more than an inch long. This monstrous formation of the outer skin, or epidermis, was transmitted by Lambert to his sons and grandsons, but not to his granddaughters. The transmission in this instance remained in the male line, as is often the case." Other similar examples are cited by Gould and Pyle,[21] and the disease is described as "a morbid development of the papillæ and thickening of the epidermic lamellæ."

Categories of Interpretation.

Having thus far examined the factors governing the origin of spines, and found that they could be grouped into a number of distinct categories, it is now desirable to interpret these results, and endeavor to arrive at the real significance of the spinose condition.

The two main generalizations which will be discussed are, first, that spinosity represents the limit of morphological variation, and second, it indicates the decline or paracme of vitality.

Spinosity a Limit to Variation.

A number of data have already been given, leading to the belief that, on becoming spinose, organisms have reached a limit of morphological variation. They may continue to develop more and more differentiated and compound spines, but no new types evolve out of such a stock.

The subject may be treated in two ways, both leading to the same conclusion. First, the stages and processes involved in the growth of a spine itself may be studied, and next the development of spines in the ontogenies and phylogenies of animals and plants may be examined.

The growth of a spine has already been described, and it was shown that this type of growth may arise from specialization of other ornamental features, such as nodes, ridges, and lamellæ, and also from the decadence of leaves, legs, etc. These observations and numberless others which could be made will be sufficient to show that almost any kind of superficial structure, as knobs, tubercles, ridges, laminæ, reticulations, etc., has by differential growth been changed into spines; also, that organs

of various kinds, as legs, branches, leaves, etc., have by atrophy been reduced to spines. In each case, the parts in their development pass through the various intermediate stages, and clearly show that the spine is a result and not a mean. Moreover, none of these structures or organs is developed through the contrary process; namely, that of beginning with spines and passing through stages corresponding to laminæ, ridges, tubercles, etc. The spine is the limit, and out of it no further structure is formed.

It is necessary to make some mention here of the movable spines of Echinoderms, which appear to form an exception to the foregoing statements. There seems to be no doubt that the fixed and movable spines, the pedicillariæ, the paxillæ, and the spheridia are homologous structures, and that all begin as spiniform skeletal outgrowths, which by subsequent growth and modification produce the structures mentioned (Agassiz[1]). The echinoderm skeleton, including spines, etc., is deposited in the midst of living tissue, and in the case of the spines cannot be directly correlated with the spines of other classes of organisms, which are either very deficient in vitality or are dead structures as soon as completed. After the movable spines of echinoderms are fully developed, the living portion is often confined to the base, and the shaft becomes simply a dead structure upon which encrusting organisms may find lodgement, a condition seldom occurring in the living spines. These finished spines never develop into anything else, and are the structures which conform to the present discussion. The embryonic condition of the spines and pedicillariæ shows that they are really more internal than external structures, and therefore remain under the full control of the ordinary processes of growth, resorption, and modification by living tissues. Furthermore, the movable spines are of such functional importance that no close homologies can be made with ordinary spines found in other classes of organisms.

In tracing the ontogeny of a spinose form, it has been found (pp. 14–17) that each species at the beginning was plain and simple, and at some later period, spines were gradually developed according to a definite sequence of stages. Usually after the maturity of the organism, the spines reach their greatest perfection, and in old age, there is first an over-production or extravagant differentiation followed by a decline of spinous growth, and ending in extreme senility with their total absence.

There are abundant reasons for believing that the radicles of groups are undifferentiated and inornate, and whenever a class has had a long existence, it has been by the continuance of such radical types or by the development of secondary or tertiary

radicles, which, though differing in internal characters, still retain a primitive simplicity in superficial features. The early stages of ontogeny of any form should agree with the radical stock, and, as already noted, these stages are simple. Hyatt[34] says on this point: "the evidence is very strong that there is a limit to the progressive complications which may take place in any type, beyond which it can only proceed by reversing the process, and retrograding. At the same time, however, the evidence is equally strong that there are such things as types which remain comparatively simple, or do not progress to the same degree as others of their own group. Among Nautiloidea and Ammonoidea these are the radicle or generator types. No case has yet been found of a highly complicated, specialized type, with a long line of descendants traceable to it as the radicle, except the progressive; and all our examples of radicles are taken from lower, simpler forms; and these radicle types are longer-lived, more persistent and less changeable in time than their descendants."

A few examples will now be taken from the life histories of large groups. In the Brachiopods, the order Protremata, containing most of the spinose forms, has 4 genera and 22 species in the Cambrian of America, 20 genera and 173 species in the Ordovician, and 30 genera in the Silurian. "Then began a steady decline, with extinction in the Carboniferous of North America. In the Triassic of Europe this order is sparingly represented by small species, and is there essentially restricted to the family Thecidiidæ, which continues to have living representatives in the Mediterranean Sea" (Schuchert[64]). The superfamily Strophomenacea of this order is the longest lived and excelled in amount of specific differentiation, there being 608 species in North America alone (Schuchert). In this superfamily the early families and genera were without spines, it being only when *Chonetes* is reached that the first spines are found in the order. In this genus, they are along the hinge, and seem to make up for the weak and obsolescent pedicle. Greater spine growth occurs in the genera *Productella* and *Productus*, where, in extreme cases, the surfaces of both valves are thickly studded. During the Carboniferous, the spiny Productii attained their maximum both in number, length of spines, and in individual size, for here occur the largest species of all Brachiopods. This was the climax. The Permian genera are chiefly degenerate forms (*Aulosteges*, *Strophalosia*), and with the close of the Paleozoic, the family Productidæ became extinct. The order Protremata, to which this family belongs, likewise underwent a rapid decline, and

only two simple types continued on into the Mesozoic, while but one declining representative is living at the present time.

Among the Ammonites, the chief spiny forms are those occurring just before the final extinction of the group and representing the beginning of the decline of the order (*Crioceras*, *Toxoceras*, *Ancyloceras*, *Hamites*, etc.). In the Dinosaurian Reptiles, the great horned forms, *Triceratops*, *Torosaurus*,[39] etc., mark the extinction of the entire order. The great horned mammals of the Eocene, the Dinocerata, have left no descendants, and the giant Brontotheridæ, after undergoing various horn modifications through the Miocene, continued no further.

It is not desirable, however, to convey the impression that the spines or horns are alone responsible for this wholesale extinction. It has been shown that they are undoubtedly often an expression of extreme specialization, and generally they represent the limits to which superficial structures may be differentiated. Although there may be other expressions for similar conditions, yet the presence of spines is one, if not the most evident, marker of the attainment of these limits. The presence of a spine on an organ or part indicates the limit of progression or regression of that part or organ. If the spinose condition is general, or if it dominates important functions, it then indicates the limit of progression and regression of the organism.

Spinosity the Paracme of Vitality.

The physiological interpretation of spinosity is a correlative of the morphological aspect of the same condition, and, as it was found that spinosity was a limit to morphological progress or regress, it will now be shown that it also indicates the paracme or decline of physiological progress. Both inferences are drawn from the individual or ontogenetic standpoint, as well as from the racial or phylogenetic.

In the spinose individual, the decline of vitality has been studied by Geddes[20] in thorny plants. He concludes that they show a "gradual death from point backwards (i. e. *ebbing vitality*)." The requisite evidence is afforded in the experience of gardeners who generally consider spiny plants as "always given to die back," or as otherwise expressed, they "often prune themselves." It is difficult to adduce the same kind of evidence among animals, though there may be some degree of semblance between this self-pruning of spiniferous plants and the growth, death, and shedding of the antlers of the modern Deer. Stronger evidence of the relations of spinosity to the organism is afforded in the consideration of spines as

consisting wholly of the mechanical tissues. They are more or less dead structures and are usually without special physiological function. Hence, in so far as the whole or a part of an organism is spinose, it represents the ratio between the mechanical and active tissues, or between the inert and living structures.

Morris[49] correlates the mechanical and motor defenses of animals and plants in a matter bearing upon this subject as follows: "If we examine the whole range of the animal kingdom, we find every phase of combination of mechanical and motor defense, the motion growing more sluggish as the defensive armor grows more efficient. But in the whole kingdom, motion persists as one of the defensive agencies. No animal exists without some power of motion, by whose aid it withdraws or otherwise escapes from danger." He also notes that the plant kingdom, with the exception of the minute, swimming forms, possesses no defensive motion, and that mechanical defense alone exists. Under mechanical defense are included thorns, spines, etc., together with chemical appliances, as in plants with poisonous or disagreeable juices. These facts lead to the conclusion that, in proportion as animals are spinose or armored, they exhibit a vegetative type of structure, and have retrograded.

It has been shown elsewhere in this article, that the greatest development of spinose organisms occurs just after the culmination of a group, and, as this period clearly represents the beginning of the decline of the vitality of the group, the spines are to be taken as the visible evidence of this decadence. A similar observation has been made by Packard,[54] who after passing in review the geological development of the Trilobites, Brachiopods, and Ammonites, states that "these types, as is well known, had their period of rise, culmination, and decline, or extinction, and the more spiny, highly ornamented, abnormal, bizarre forms appeared at or about the time when the vitality of the type was apparently declining."

Furthermore, it is now commonly agreed that all groups have been most plastic near their point of origin, or, in other words, that during their early history, all the important or major types of structure have been developed. Their subsequent history reveals the amount of minor differentiation and specialization they have undergone. Apparently, most of the early impulses of growth, whether from the environment or from vital forces, resulted in physiological changes producing fundamental variations in function and structure. The later influences of environment and growth force are expressed in peripheral differentiation, and show that the racial or earlier characters had become fixed, and that the later or specific

features were the chief variables. The stimuli which, during the early life history of a group, were expended in internal or physiological adjustments, later produce external differentiation, and in this differentiation, spinosity is the limit. The presence of spines, therefore, indicates the fixity of the primary physiological characters, together with the consequent inability of the organism to change due to its decreasing vitality.

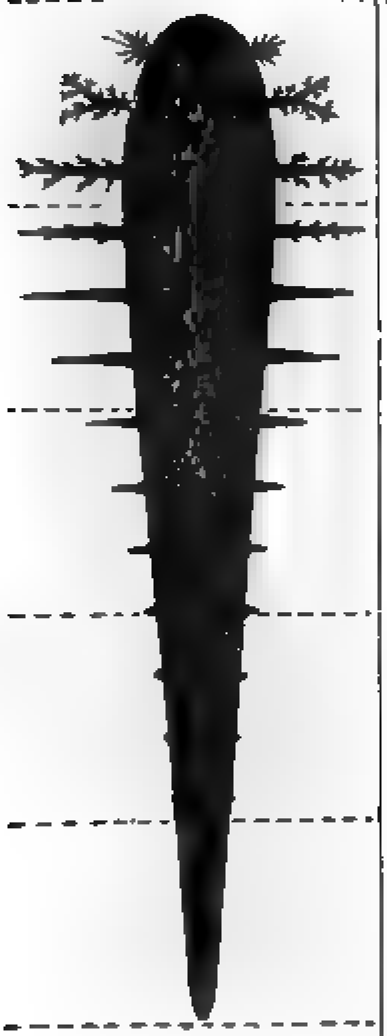
Conclusion.

Just as all our features of terrestrial topography are included between the limits of plains and mountains, and the mountains are considered as the limit of progressive accidentation, so the spines of animals or the monticules and pinnacles of their surface may be considered as the limits of progressive differentiation. The primitive base level, or peneplain, becomes elevated, and by erosion is cut up into table lands, mèsas, and buttes, with intersecting valleys. The valleys are gradually deepened, and the country becomes rougher until a maximum is reached. Then follows a reduction of the inequalities of the surface, and finally in old age, the smooth, gently rounded outlines of geographic infancy again appear. So in organisms, the smooth rounded embryo or larval form progressively acquires more and more pronounced and highly differentiated characters through youth and maturity. In old age, it blossoms out with a galaxy of spines, and with further decadence produces extravagant vagaries of spines, but in extreme senility comes the second childhood, with its simple growth and the last feeble infantile exhibit of vital power.

The history of a group of animals is the same. The first species are small and unornamented. They increase in size, complexity, and diversity, until the culmination, when most of the spinose forms begin to appear. During the decline, extravagant types are apt to develop, and if the end is not then reached, the group is continued in the small and unspecialized species, which did not partake of the general tendency to spinous growth.

Lastly, it must be determined whether spines are really hereditable characters, and therefore can be used in studying the phylogenies of groups. No one has yet been able to show any type or set of characters which cannot be transmitted from parent to offspring. Hyatt[34] says: "Everything is inherited or inheritable, so far as can be judged by the behavior of characteristics." Furthermore, in a review of animal life, extinct and living, no one can fail to be impressed with the fact that, especially near the close of the life history of a group, or in a series of highly specialized forms, spinose characters are often considered as of supra-varietal value, and are rated of specific,

generic, and sometimes of family rank, or even higher. They have therefore acquired a fixed importance in these special groups, and are recognized in the same categories with physiological and structural characters. The differences which appear at an early period in higher genera are the bases of distinction among lower genera. If the spines or other similar features do not make their appearance in an individual until a late adolescent stage, they are usually of negative value in a scheme of classification. This agrees with the general principle recently suggested by Harris,[17] that when the main features of the ornament (= spines, etc.) are foreshadowed in the larval and early adolescent stages, they are to be regarded as of taxonomic value.



Ontogeny stages.	Ontogeny condition.	Phylogeny stages.	Phylogeny condition.	Chronology.
Old age or gerontic	Paraplasis	Phylogerontic	Paracme	5
Adult or ephebic	Metaplasis	Phylephebic	Acme	4
Immature or neanic	Anaplasis	Phyloneanic	Epacme	3
Larval or nepionic	Anaplasis	Phylonepionic	Epacme	2
Embryonic	Anaplasis	Phylembryonic	Epacme	1

Diagram and table showing correlation of stages and conditions of development in the spinose individual, in its ancestry, and in time.

The preceding diagram illustrates the previous statements, and shows the correlation between the stages and conditions of growth in the ontogeny of a spinose individual, with its phylogeny, and also the chronology of groups containing spinose

forms. The numbers indicating chronology simply refer to successive periods of time. In particular cases, they may be long geologic ages as Cambrian, Ordovician, Silurian, Devonian, and Carboniferous, or in other instances they may represent much shorter periods.

From the study of the ontogenies of spinose forms, it has already been ascertained that they were simple and inornate during their young stages; and from the phylogenies of the same and similar forms, it was likewise learned that they were all derived from non-spinose ancestors. It has also been shown that spines represent an extreme of superficial differentiation which may become fixed in ontogeny, and the further conclusion, that spinosity represents a limit to morphological and physiological variation, has been reached. Finally, it is evident that, after attaining the limit of spine differentiation, spinose organisms leave no descendants, and also that out of spinose types no new types are developed.

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TABLE OF CONTENTS.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On Neon and Metargon, companions of Argon in Atmospheric Air.*—On the 16th of June, Ramsay and Travers announced to the Royal Society the discovery of two new elements associated with argon in atmospheric air. Having about 18 liters of argon available, this was allowed to enter a small bulb immersed in liquefied air boiling under reduced pressure. The argon readily liquefied; and after 13 or 14 liters had disappeared, portions of the residual gas of about 50 or 60^{cc} (which evidently must contain the light gas suspected to be present) were collected, sparked with oxygen over soda, and the spectrum examined. It was found to be characterized by a number of bright red lines, among which one was particularly brilliant, and a bright yellow line, the green and blue lines being numerous but weak. The yellow line had a wave-length of 5849·6; so that it is not identical with that of sodium, helium or krypton, though resembling it in intensity. These wave lengths are as follows: Na (D_1) 5895·0; Na (D_2) 5889·0; He (D_3) 5875·9; Kr (D_4) 5866·5; Ne (D_5) 5849·6. Hence the authors propose the name "*neon*" (new) for the new gas. By means of a bulb of 32·35^{cc} capacity, the density of this neon was found to be 14·67. Since to bring it to its proper place in the periodic system, a density of 10 or 11 is required, the gas examined, if the density of argon be 20 and that of pure neon be 10, would contain 53·3 per cent of it.* That this gas—which appears to be the substance hinted at in Ramsay's Toronto address—is really new seems to be proved, not only by its spectrum and by its low density, but also by its behavior in a vacuum tube. Unlike helium, argon and krypton, it is rapidly absorbed by the red-hot aluminum electrodes, and as the pressure falls the appearance of the tube changes from a fiery red to a brilliant orange; a phenomenon shown by no other gas. Moreover, it is monatomic.

During the liquefaction of the argon, a considerable quantity of a white solid was observed to separate, in part round the sides of the tube and in part beneath the surface of the liquid. On distilling off the liquid argon, this white solid evaporated very slowly, so that finally it remained alone in the bulb. This bulb was then connected with mercury reservoirs and two fractions of about 70 or 80^{cc} each, consisting of the gas from the volatilized solid, were collected. In a vacuum tube, this gas showed a very complex spectrum. With low dispersion, it appeared banded; but with a grating, equidistant single bright lines appear throughout the spectrum, with fainter ones intermediate. The bright lines in the green are: first band, 5632·5, 5583·0, 5537·0; second band, 5163·0, 5126·5. In the first blue band 4733·5, 4711·5; second blue band, 4604·5; third blue band (1st order), 4314·0;

* On subsequent fractionation, the density decreased to 13·7.

fourth blue band (2d order), 4213·5; fifth blue band (1st order), about 3878. The red pair of argon lines were also faintly visible. The density of this gas, determined as before, was 19·87, not differing sensibly from that of argon. On determining the ratio of specific heats for this new gas, it was found to be 1·660; thus showing that it is monatomic like neon. From the fact that, both in its spectrum, and in its behavior at low temperatures, this gas differs very markedly from argon, the authors regard it as a distinct elementary substance and propose for it the name "*metargon*"; suggesting that it stands to argon as nickel does to cobalt, having approximately the same atomic mass but different properties. The reason that krypton does not appear in the higher fraction of argon, the authors explain by the fact first, that to prepare it, the manipulation of no less than 60000 times the volume of the impure sample they obtained, was required; and second, that while metargon is a solid at the temperature of boiling air, krypton is probably a liquid and so more volatile. Moreover the liquid air from which the krypton had been obtained had been previously filtered.—*Chem. News*, lxxviii, 1, July, 1898; *C. R.*, cxxvi, 1762, June, 1898. G. F. B.

2. *On Metargon.*—It has been pointed out by DEWAR that on liquefying a sample of argon obtained from Lord Rayleigh, about 250^{cc} in volume, contained in a bulb with a quill tube attachment, by immersion in liquid air, it always yields a perfectly clear liquid free from turbidity or opalescence. Since very small fractions of a per cent of impurity in a gaseous substance, separating as a solid, can be readily detected in this way, for example the 0·04 per cent of carbon dioxide in dry air or 0·1 per cent of chlorine in oxygen, it is remarkable that one per cent of a gas giving a white solid at the temperature of liquid air, could escape detection if it existed in the sample of argon furnished by Lord Rayleigh.—*Chem. News*, lxxviii, 70, August, 1898. G. F. B.

3. *On the Density and Boiling Point of liquid Hydrogen.*—At the meeting of the Chemical Society on June 2d, DEWAR gave further facts concerning liquid hydrogen. Its boiling point in air determined by a platinum resistance thermometer was found to be 35° absolute or −238° C.; a value higher by about 17 per cent than the value which Olszewski obtained by adiabatic expansion. Since its critical point must be about 50° absolute, the whole range of liquid hydrogen is only about 50° absolute. Hence there can be only a few degrees + or − difference in the estimates of the boiling point deduced from theory; though in fact this is a large percentage of the whole, the range being so small. Hence we may predict almost certainly that with no conceivable means at our present command, shall we ever be able to get nearer the absolute zero than −250° C., or say +20° absolute. In other words, the practical fall in temperature given by liquid hydrogen under high exhaustion will never exceed 10° or 15° below the present boiling point. As to its density, since it appears as a transparent liquid, having a well-defined meniscus,

and dropping readily from one vessel to another, a density not unlike that of marsh gas would be suggested; this being 0·41 at its boiling point in air. By allowing 10^{cc} of liquid hydrogen to evaporate, collecting the gas and measuring its volume, the approximate density, however, was found to be rather less than 0·07. The liquid therefore is about one-fourteenth the density of water; *i. e.*, it bears to water the same relation that gaseous hydrogen does to air. Hence the atomic volume of liquid hydrogen is about 14, that of liquid oxygen being about 13·7; the atomic volumes at their respective boiling points being very near each other. The density of hydrogen vapor at its boiling point is about one-half that of air; approaching that of marsh gas. The ratio of hydrogen vapor to the liquid is as 1:100, whereas this ratio in the case of oxygen is 1:255. "Liquid hydrogen is in all respects the most extraordinary fluid chemists have ever had to deal with. No chemist could have anticipated that a liquid with a density of one-fourteenth that of water could have been capable of collection and manipulation in vacuum vessels with the same ease practically as manipulation with liquid air was carried on ten years ago and that by its means we shall approach within 20° or 25° of the absolute zero."—*Chem. News*, lxxvii, 261, June, 1898. G. F. B.

4. *On the Boiling Point of Liquid Ozone.*—Ozone was obtained as a liquid, indigo-blue in color, by Hautefeuille and Chappuis in 1882. In 1887 Oslzewski roughly fixed its boiling point at −106°. TROOST has now repeated the experiment and has determined the boiling point with greater accuracy. The ozone was obtained by means of a Berthelot ozonizer, kept at −79° by a mixture of solid carbon dioxide and methyl chloride. The liquefaction was effected in a vertical tube, the lower portion of which was immersed in a bath of liquid oxygen contained in a Dewar double bulb. The ozone liquefies before reaching the part of the tube thus immersed, and collects in small drops having an oily appearance and not wetting the glass. An iron-constantin couple was employed to fix the temperature, used in connection with a Deprez-d'Arsonval galvanometer. A curve was obtained for the apparatus using the temperatures of melting ice, of boiling methyl chloride, of mixtures of solid carbon dioxide and methyl chloride (controlled by the hydrogen thermometer), of boiling nitrous oxide, of liquid ethylene, of melting solid ethylene and of the boiling point of oxygen. In this way the temperature could be read to within half a degree. One of the junctions of the thermo-couple was placed in the liquid ozone, the other was placed in melting ice. The bath of liquid oxygen was thus lowered until its free surface was about 3^{cm} below the lower end of the tube containing the ozone, and the galvanometer deflections were noted. At first they decreased, but finally became steady, remaining so during the time that the ozone was in ebullition, when they fell again rapidly. Transferred to the curve, the stationary point corresponds to a temperature of −119°.

Repetition of the experiment gave uniformly the same result. The boiling point of liquid ozone at the atmospheric pressure may therefore be taken as $-119°$. The liquid oxygen required in these experiments was obtained by the use of a Dewar apparatus utilizing commercial compressed oxygen expanded after having traversed a long serpentine tube cooled to $-79°$. In this way, in less than half an hour, a quarter of a liter of liquid oxygen can be obtained in the laboratory or lecture room, without the use of compression pumps or motive power.—*C. R.*, cxxvi, 1751, June, 1898; *Chem. News*, lxxviii, 29, July, 1898. G. F. B.

II. Miscellaneous Scientific Intelligence.

1. *American Association for the Advancement of Science.*—The fiftieth anniversary meeting of the American Association was held at Boston from the 20th to the 27th of August. The President of the meeting was Prof. F. W. Putnam of Cambridge, who has long been identified with the Association, having performed the arduous duties of Permanent Secretary for some twenty-five years. The retiring President, Dr. Wolcott Gibbs of Newport, delivered an address upon the subject "On Some Points in Theoretical Chemistry"; this is printed in full in the issue of *Science* for August 26. Addresses were also given by the Vice-Presidents of the various Sections.

The meeting was one of the largest in the history of the Association, the total registration being 903, a number surpassed only three times, once at Boston and on two other occasions when the meetings were held in conjunction with the British Association. The list of papers given below shows also a large number of entries. The place of meeting offered many attractions, both scientific and social, and the members of the local Committee did everything in their power to make the occasion successful. The numerous excursions were largely attended and highly appreciated.

The place selected for the next meeting of the Association is Columbus, Ohio, and Pres. Edward Orton, of the Ohio State University, has been elected President. The Vice-Presidents of the several sections are as follows: Section A, Alexander MacFarlane; Section B, Elihu Thomson; Section C, F. P. Venable; Section D, Storm Bull; Section E, J. F. Whiteaves; Section F, Simon H. Gage; Section G, Charles R. Barnes; Section H, Thomas Wilson; Section I, Marcus Benjamin.

The following is a list of papers accepted for reading:

Section A. *Mathematics and Astronomy.*

Mary Proctor: Making Astronomy popular.

Henry M. Parkhurst: Correction of local error in stellar photometry.

H. S. Davis: The parallaxes of 61^1 and 61^2 Cygni from a reduction of the Rutherfurd measures.

Frank Schlesinger: The Praesepe Group: measurement and reduction of the Rutherfurd photographs.

J. R. Eastman: Discordances between the north polar distances of stars derived from direct and reflected observations. The treatment of results from reflection observations at the Greenwich Observatory.

A. E. DOUGLASS: Summary of planetary work at the Lowell Observatory.

LEWIS SWIFT: Astronomy in Southern California.

F. W. COAR: Description of instantaneous azimuth and altitude charts of the heavens.

W. MAXWELL REED: Instruction in Elementary Astronomy by means of observations made by the student.

TRUMAN H. SAFFORD: Personal equations during the past century.

ARTEMUS MARTIN: Rational right-angled triangles.

J. WOODBRIDGE DAVIS: Behavior of the atmospheres of gas- and vapor-generating globes in celestial space.

ELLEN HAYES: Graphical Logic.

FRANK H. LOUD: Illustrations of the comitant method of constructing the imaginary loci of Analytical Geometry, so as to render their properties evident to the eye.

R. S. WOODWARD: The mass and moments of inertia of the earth's atmosphere. Two new forms of apparatus for measuring the acceleration of gravity. The gravitation constant and the mean density of the earth.

G. A. MILLER: The operation groups of Order 48 and those of Order $2p^3$, p being any prime number.

G. W. HOUGH: The condition of the surface of the Planet Jupiter.

GEO. E. HALE: The Yerkes Observatory and its work.

EDGAR ODELL LOVETT: General theory of anharmonics.

E. D. PRESTON: Fifty years of American Geodesy.

WILLIAM EIMBECK: The duplex base apparatus of the U. S. Coast and Geodetic Survey. Diminution of the refraction of the atmosphere with height and its effect upon trigonometrically determined elevations from reciprocal zenith distances.

ALEXANDER MACFARLANE: On the aims of the International Society for the Promotion of Quaternions and allied branches.

S. EDWARD WARREN: Some notes on "direction."

FRANKLIN A. BECHER: A short method for deriving Riemann's Theta formula.

L. E. DICKSON: A ternary and a quaternary linear congruence group simply isomorphic to the linear fractional congruence group.

A. S. HATHAWAY: Linear transformations in four dimensions.

JOHN S. HAYFORD: The limitations of the present solution of the tidal problem.

J. K. REES, HAROLD JACOBY, and Dr. H. S. DAVIS: Variation of latitude at New York City and the constant of aberration from observations with a zenith telescope at Columbia University Observatory, 1892–1898.

GEORGE A. HILL: Description of the altazimuth instrument recently constructed for the U. S. Naval Observatory.

DAVID P. TODD: New application of the prismatic camera to total eclipse.

ROLLIN A. HARRIS: On harmonic functions. A proposed tidal analyzer. A tidal abacus. The harmonic analysis of high and low waters.

ERNEST W. BROWN: Report on the recent progress in the dynamics of solids and fluids.

HENRY S. WHITE: Report on theory of invariants: the chief contributions of a decade.

ARTHUR G. WEBSTER: Report on the recent progress in the mathematical theory of electricity and magnetism.

G. A. MILLER: Report on the modern group theory.

SECTION B. *Physics.*

E. H. HALL: The measurement of thermal conductivity in iron.

L. A. BAUER: On energy and entropy. Second report on the magnetic survey of Maryland.

ERNEST MERRITT: On the magnetic deflection of diffusely reflected cathode rays. The resistance of iron wires for alternating currents of ordinary frequencies.

ERNEST MERRITT and O. M. STEWART: On the electrical properties of the vapor from the arc.

E. L. NICHOLS: The heat of fusion of ice determined in electrical units.

A. M. THIESSEN: The hysteresis of iron and steel at ordinary temperatures and at the temperature of solid carbon dioxide.

G. W. Gressman: The electrical resistance of lead amalgams at low temperatures.

F. Bedell, R. M. Klein and T. P. Thompson: The most efficient thickness of transformer plate.

N. H. Brown: Photographic studies of the electric arc.

Carl Barus: Exhibition of certain models in physics and dynamics.

F. H. Bigelow: Temperature and vapor gradients in the atmosphere.

E. W. Morley, H. T. Eddy and D. C. Miller: Report on the velocity of light in a magnetic field.

D. C. Miller: A study of standard meter scales ruled on nickel, silver and glass. Exhibit of an automatic mercurial air pump designed by Prof. E. W. Morley.

S. T. Moreland: An apparatus for determining coefficients of induction.

J. O. Thompson: Study of elastic fatigue by the time-variation of the logarithmic decrement.

G. W. Patterson and Karl E. Guthe: A redetermination of the ampere.

Karl E. Guthe: Polarization and internal resistance of the voltaic cell.

Charles F. Brush: A new gas.

Henry S. Webb: Hysteresis loss in iron for very small ranges of induction.

W. S. Franklin: Note on the testing of optical glass. A lecture room experiment in electrostatics.

Barry McNutt: A study of galvanic polarization.

S. S. Clark: On a normal curve of magnetization of iron.

Thomas Gray: Some determinations of dielectric strength.

H. T. Eddy: Graphical treatment of mutually inductive circuits with special reference to the case of variable frequency.

E. Rhoads: The effect of fibrous structure in iron on its change of length when magnetized.

A. Lawrence Rotch: Progress in the exploration of the air with kites at the Blue Hill Observatory.

C. L. Norton: The use of window glass having a diffusive action on light.

F. P. Whitman: The relative brightness of pigments by oblique vision.

F. C. Caldwell: Notes on the effect of silicon on the magnetic permeability of iron.

H. M. Goodwin and G. K. Burgess: The osmotic pressure of certain ether solutions and the validity of the Boyle-Van't Hoff law.

H. M. Goodwin and M. de Kay Thompson: The dielectric constant and electrical conductivity of liquid ammonia.

A. G. Webster and B. F. Sharpe: A new instrument for the measurement of the intensity of sound.

A. G. Webster: A new chronograph and a means of rating tuning forks. A geometrical method for investigating diffraction by a circular aperture.

A. D. Cole: The measurement of electrical oscillations of short period and their absorption by water.

J. H. Smith: The effect of the secondary on the period of oscillation in a primary condenser circuit.

Levi Orser: A harmonic piano and organ.

E. B. Rosa and A. W. Smith: The efficiency of condensers. A calorimetric determination of the energy dissipated in condensers.

J. O. Reed: An acoustical micrometer.

Knût Ångström: An instrument for measuring radiance.

C. P. Matthews: A device for recording photometer readings.

W. A. Anthony: Polarization in the Zn-H_2SO_4 cell.

Section C. *Chemistry.*

H.. W. Wiley: The influence of temperature upon the specific rotary power of sucrose.

W. A. Noyes and N. M. Austin: The determination of water and coke in coal.

W. F. Hillebrand: Notes on determination of water in coal.

Charles E. Munroe: Analysis of mixed acids.

S. P. Mulliken and Harwood Scudder: A simple color reaction for the detection of methyl alcohol.

S. P. MULLIKEN and E. R. BARKER: Detection of the nitro group in organic compounds.

E. D. CAMPBELL and E. C. CHAMPION: Electrolytic determination of tin in tin ores.

HERMAN POOLE: The determination of undigested fat and casein in infant feces.

A. C. LANGMUIR: New method for the determination of zinc. Note on determination of arsenic in glycerine.

H. W. WILEY and F. P. VEITCH: The estimation of iron and aluminum in natural phosphates.

H. L. WELLS: Double salts.

F. W. CLARKE: The alkaline reaction of certain natural silicates.

ELLEN H. RICHARDS and WILLIS R. WHITNEY: The action of soft waters on metals.

C. LORING JACKSON and J. H. DERBY: Ferrous iodide.

CHAS. L. REESE: The action of chromic acid on hydrogen.

J. H. KASTLE: On the occurrence of strontium and barium. The oxidation of formic aldehyde by hydrogen peroxide.

J. L. HOWE and E. A. O'NEAL: Use of electric current in forming alums.

J. L. HOWE and S. G. HAMNER: The color of sulphur in the gaseous state.

CABELL WHITEHEAD: A study of the tellurides.

W. L. DUDLEY: Magnetic ferric oxide.

C. WELLINGTON: The action of various bases on metallic arsenites.

C. F. MABERY and W. O. QUAYLE: The sulphur compounds and unsaturated compounds in Canadian petroleum.

C. F. MABERY: The composition of commercial paraffine and the higher constituents of Pennsylvania petroleum.

C. F. MABERY and E. J. HUDSON: The constituents of California petroleum.

C. F. MABERY and H. L. SCHROM: Some experiments on the addition of hydrogen to acetylene.

C. LORING JACKSON: Certain peculiar reactions of the tribromnitrobenzols.

PETER FIREMAN and E. G. PORTNER: The propyl phosphines.

PETER FIREMAN aud ERNESTINE FIREMAN: The action of ethers on phosphonium iodide.

W. A. NOYES: Camphoric acid: synthesis of the neighboring xylic acid.

M. GOMBERG: On tetraphenylmethane. A periodide of bromtriphenylmethane.

M. GOMBERG and A. C. CAMPBELL: Hydrazo- and azo-derivatives of tetraphenylmethane.

SAMUEL P. MULLIKEN and W. KELLEY: Oxyinduline—a new blue dyestuff.

FRANK K. CAMERON: The benzaldoximes.

A. B. PRESCOTT and H. M. GORDIN: Certain alkaloidal periodides and the volumetric estimation of alkaloids as higher periodides.

E. KNEUER: On true and bis-nitroso compounds.

T. W. RICHARDS: Progress in physical chemistry.

E. C. FRANKLIN and C. A. KRAUS: Some properties of liquid anhydrous ammonia.

A. A. NOYES and DAVID SCHWARTZ: The solubility of di-ionic salts of weak acids in solutions of stronger di-ionic acids.

A. A. NOYES and E. S. CHAPIN: The solubility of di-ionic acids in solutions of di-ionic salts of other acids. The solubility of tri-ionic bases in solutions of di-ionic salts of weak bases.

A. A. NOYES and L. J. SEIDENSTICKER: The solubility of iodine in dilute potassium iodide solutions.

A. A. NOYES and GEORGE T. COTTLE: The rate of reaction between silver acetate and sodium formate: a reaction of the third order.

E. D. CAMPBELL and W. E. HARTMAN: On the influence of silicon on the heat of solution of coke in cast iron.

C. GILBERT WHEELER: On the passage of bubbles through media of different densities.

ROMEYN HITCHCOCK: Photographic reproduction of color.

N. W. LORD: The valuation of coals.

W. P. MASON: Determination of turbidity in water. Efficiency of the Elmira ing plant.

ISABELLE F. HYAMS and ELLEN H. RICHARDS: On the composition of *Oscillaria prolifica* and its relation to the quality of water supplies.

CHAS. L. PARSONS: The Le Seuer electrolytic process for the production of caustic soda and bleaching powder. Review of the electrolytic processes for the production of caustic soda and bleaching powder.

E. G. SMITH: The alum question in water purification.

C. F. MABERY and K. LANDGREBE: The effect of an electrolytic bath on the tanning of leather.

WM. MCMURTRIE: Some records of the year's progress in applied chemistry.

BRUNO TERNE: The progress in utilization of city garbage, with special reference to the new plant in Boston.

C. F. MABERY and E. B. BALTZLY: On the removal of hardness from water for boiling purposes.

S. M. BABCOCK and H. L. RUSSELL: On the properties of galactose.

O. W. SMITH and NORMAN PARKS: Composition of Ohio wines.

ROMEYN HITCHCOCK: New process for the commercial production of oxygen.

H. A. WEBER: Light: a factor in sugar production.

J. B. LINDSAY: The determination of starch in agricultural products.

E. W. HILGARD: A note on the growth of lupins on calcareous lands.

E. A. DE SCHWEINITZ: Some of the important results of the recent chemical investigations of plant and animal cells.

F. P. VENABLE: The use of the formula in teaching chemistry.

IRA REMSEN: The teaching of organic chemistry.

EDWARD HART: The teaching of industrial chemistry.

WM. L. DUDLEY: The teaching of analytical chemistry.

SECTION D. *Mechanical Science and Engineering.*

C. L. CRANDALL: The determination of the lamp-hours per day available for electric lighting from a storage battery plant driven by a 12-foot Aer-motor.

F. H. NEWELL: Instruments and methods of hydrographic measurements by the United States Geological Survey.

CHARLES D. WALCOTT: The development of the topographic work of the United States Geological Survey and its application to the solution of economic and engineering problems.

CHAS. L. NORTON: On the testing of steam pipe covers.

J. B. JOHNSON: Time test on dry long leaf yellow pine lumber in compression endwise. Some micro-photographs, showing the grains of Portland cement between diameters $0{\cdot}02^{mm}$ and $0{\cdot}14^{mm}$ as separated by the Schöne washing apparatus.

CHARLES F. WARNER: High speed influence machines.

CARL KINSLEY: Proposed methods of determining the frequency of alternating currents.

ROMEYN HITCHCOCK: The theory of half-tone press printing.

JOHN J. FLATHER: A combined absorption and transmission dynamometer.

F. C. WAGNER: On the use of a platinum resistance as a pyrometer in boiler tests. On the measurement of train resistance by dynamometer.

THOMAS GRAY: Note on a curious example of elastic eolotropy in steel. An integrating dynamometer for measuring the work done in drawing a train. A comparison of the efficiency of the rheostat and the series-parallel controller for electric cars.

STORM BULL: The efficiency of refrigerating plants.

L. G. CARPENTER: On the evaporation and seepage from reservoirs. Losses from rivers. Energy received from the sun.

WM. KENT: Some notes on definitions of mechanical unit.

SECTION E. *Geology and Geography.*

B. K. EMERSON: Outline map of the geology of Southern New England.

H. L. FAIRCHILD: Basins in glacial lake deltas.

A. C. HAMLIN: An exhibition of the rare gems and minerals of Mt. Mica.

C. H. HITCHCOCK: The Hudson River lobe of the Laurentide ice-sheet

ARTHUR HOLLICK: The age of the Amboy clay series as indicated by its flora.

T. C. HOPKINS: The origin of the limonite ores of Nittany Valley, Pennsylvania.

H. C. Hovey: The region of the Causses in Southern France, with maps and stereopticon views.

C. H. Richardson: The Washington limestone in Vermont.

Warren Upham: Fluctuations of North American glaciation shown by interglacial soils and fossiliferous deposits. Time of erosion of the Upper Mississippi, Minnesota, and St. Croix Valleys.

G. Frederick Wright: Supposed "Corduroy Road" of Late Glacial age, at Amboy, Ohio. The age of Niagara Falls as indicated by the erosion at the mouth of the gorge. A recently discovered cave of celestite crystals at Put-in-Bay, Ohio.

M. A. Veeder: Changes in the drainage system in the vicinity of Lake Ontario during the Glacial period.

John Crawford: Recent severe seismic movements in Nicaragua.

J. W. Spencer: Another episode in the history of Niagara River. Evidence of recent great elevation of New England.

Benjamin Howard: Geography and resources of the Siberian Island of Sakhalin.

G. F. Matthew: The oldest Palæozoic fauna.

N. H. Winchell: The oldest known rock. The origin of the Archean igneous rocks.

C. R. Van Hise: Joints in rocks.

E. O. Hovey: Notes on some European museums.

W. O. Crosby: History of the Blue Hills complex.

Amadeus W. Grabau: Palæontology of the Cambrian terranes of the Boston basin.

E. M. Souvielle: Diamonds in meteorites.

Harry F. Reid: The periodic variations of glaciers.

(*Papers presented by the Geological Society.*)

Arthur Hollick: Some features of the drift on Staten Island, N. Y.

N. S. Shaler: Loess deposits of Montana. Spacing of rivers with reference to the hypothesis of base-leveling.

H. L. Fairchild: Glacial waters in the Finger Lake region of New York.

H. F. Reid: The stratification of glaciers.

Warren Upham: Evidence of epeirogenic movements causing and terminating the ice age.

G. Frederick Wright: Clayey bands of the glacial delta of the Cuyahoga River at Cleveland, O.

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C. R. Van Hise: The volume relations of original and secondary minerals in rocks.

W. G. Tight: The development of the Ohio river.

F. P. Gulliver: Classification of coastal forms. Dissection of the Ural Mountains. Note on Monadnock.

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Charles H. Fitch: The five civilized tribes and the topographic survey of Indian territory.

R. U. Goode: Bitter Root forest reserve.

SECTION F. *Zoology.*

ALPHEUS HYATT: Evolution and migration of Hawaiian land shells. A new classification of fossil Cephalopods.

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A. S. PACKARD: On the systematic position of the trilobites. On the Carboniferous fauna of Rhode Island. On the markings of Nodontian larvæ.

F. P. GORHAM: Some points in the Oögenesis of *Virbius zostericola* Smith. A new species of pigment producing pathogenic bacillus.

C. S. MINOT: On the types of vertebrate embryos. On the embryology of the rabbit.

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W. H. ASHMEAD: On the genitalia of ants, and their value in classification.

E. O. HOVEY: Naples station: general description and notes on methods of work employed there. General statement of types and figured specimens of fossil invertebrates in the American Museum of Natural History. Measurements of two large lobsters, recently added to the collections of the American Museum of Natural History.

WM. H. DALL: On the present state of our knowledge of the North American Tertiary mollusk-fauna.

C. R. EASTMAN: Some new points in Dinichthyid.

W. GRABAU: Moniloporidæ, a new family of Palæozoic corals.

JOHN MURDOCH: An Historical notice of Ross' rosy gull, *Rhodostethia rosea.*

T. JACKSON: Localized stages in growth.

THEO. GILL: On the piscine ancestors of the Amphibians.

JAS. LEWIS HOWE: Variation in the shell of *Helix nemoralis* in the Lexington, Va., Colony.

S. H. GAGE: Hibernation, transformation, and growth of the common toad (*Bufo lentiginosus americanus.*) The transformation of the brook lamprey (*Lampera wilderi*) and parasitism among lampreys.

W. L. POTEAT: Leidy's genus Ouramœba.

C. M. WEED: The winter food of the chickadee.

T. JACKSON: Ink and paper for museum labels.

W. B. ALWOOD: Notes on life history of *Protoparce carolina.* The life history of *Schizoneura lanigera.*

EDWARD S. MORSE: Remarks on Aphorphora.

HARRISON G. DYAR: The phylogeny of the North American Eucleidæ.

G. W. FIELD: On the anatomy and physiology of the spermatozoa of invertebrated animals.

C. B. DAVENPORT: Fauna of Cold Spring Harbor.

SECTION G. *Botany.*

BRADLEY M. DAVIS: The carposporic type of reproduction of Rhodophyceæ.

H. J. WEBBER: Origin and homologies of blepharoplasts. Notes on the strand flora of Florida.

W. J. BEAL: Leaves of red Astrachan apples immune from the attack of *Gymnosporangium macropus.* The work performed by the Agricultural College toward a Botanical Survey of Michigan. Some examples illustrating modes of seed dispersion. Remarkable decrease in the size of leaves of *Kalmia angustifolia*, apparently due to reduction of light.

BYRON D. HALSTED: Starch distribution as affected by fungi. Half shade and vegetation. Influence of a wet spring on parasitic fungi.

ERNST A. BESSEY: The comparative anatomy of the pistils of apocarpous families.

W. R. SHAW: The blepharoplast in the spermatogenesis of Marsilia.

C. S. CRANDALL: Observations on the relative moisture content of fruit trees in winter and in summer.

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C. O. TOWNSEND: The effect of an atmosphere of ether upon seeds and spores.

RODNEY H. TRUE: The toxic action of a certain group of compounds.

C. L. POLLARD: Types of vegetation on the keys of South Florida.

E. F. SMITH: Potato as a culture medium, with some notes on a synthesized substitute. Some little used culture media which have proved valuable for species differentiation. Observations on Stewart's sweet-corn germ.

D. T. MCDOUGAL: Temperature and transportation of desert plants.

W. ALWOOD: The brown spot disease of apple leaves, *Phyllosticta pirina*, and fungus forms associated therewith. On the occurrence of a yeast form in the life cycle of *Sphaeropsis malorum* Peck.

H. VON SCHRENK: Notes on some diseases of Southern pines.

D. G. FAIRCHILD: The Botanic garden at Buitenzorg, Java.

CHARLES E. BESSEY: Notes on the relative infrequency of fungi upon the Trans-Missouri Plains and the adjacent foothills of the Rocky Mountains.

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KATHERINE E. GOLDEN: Deterrent action of salt in yeast fermentation.

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RODNEY H. TRUE: Notes on the physiology of the sporophyte of certain mosses.

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P. BEVERIDGE KENNEDY: The morphology and taxonomic value of the fruits of grasses.

L. H. PAMMEL: The caryopsis of the Graminiæ. The ecological distribution of Colorado and Wyoming plants.

F. WILLIAM RANE: Fertilization of the muskmelon flower. Notes on destroying *Comptonia asplenifolia.* Length of time from blossoming until seed development of *Leucanthemum vulgare.*

(*Papers presented by the Botanical Society.*)

M. L. FERNALD: Note on the influence of eskers upon plant distribution in Maine.

K. M. WIEGAND: Some peculiar features of synapsis in the pollen-mother cells of monocotyledons. Is the present treatment of the species of *Hydrophyllum* a natural one?

HERMAN VON SCHRENK: The future growth of *Taxodium distichum.*

JOHN F. COWELL: Progress of work on the Buffalo Botanic Garden.

B. M. DUGGAR: The nucleolus during the division of the pollen-mother cells in *Begonia.*

E. J. DURAND: An apparatus for washing. Material killed by certain fixtures.

HOLLIS WEBSTER: Notes on the occurrence near Boston of some fleshy fungi.

B. M. DUGGAR: The influence of temperature upon *Sporotrichum globuliferum.*

A. B. SEYMOUR: North American Ustilagineæ.

SECTION H. *Anthropology.*

D. G. BRINTON: Typological analysis. Anthropological terminology.

J. W. POWELL: Sophiology, or the science of the evolution of opinion.

W. J. McGEE: Papago medicine. Some definitions in anthropology.

W. H. HOLMES: Anthropological problems of the Pacific Slope. Museum presentation of anthropology.

ALICE C. FLETCHER: The significance of the garment, a study of the Omaha Tribe.

ALICE C. FLETCHER and W. MATTHEWS: The earth lodge.

J. C. FILLMORE: The harmonic structure of Indian songs.

FRANCIS LA FLESCHE: Ritual of the Sacred Pole of the Omahas. (Phonograph Records.)

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A. L. KROEBER: The Smith Sound Eskimo.

HUGH H. LUSK: The Maori of New Zealand; his history and country.

DEAN C. WORCESTER: "Moros," or Malay pirates of the Southern Philippines. The Philippine Islands and their people.

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FRANK H. CUSHING: Tomahawk and shield. Examples of primitive fire-working from Florida.

THOMAS WILSON: Art in prehistoric times. Prehistoric musical instruments. Arrow-points, spear-heads and knives.

WILLIAM WALLACE TOOKER: Problem of the Rechahecrian Indians of Virginia. The Swastica and other marks among the Eastern Algonkins, a preliminary study.

STANSBURY HAGAR: The water burial time.

R. J. FLOODY: Time-reckoning among early people. The rite of circumcision among the early races.

DANIEL FOLKMAR: Anthropology, not sociology, as an adequate philosophy.

M. A. CLANCEY: Science the basis of morals.

A. HRDLICKA: Anthropological differences between typical white and negro girls of the same age. Variations of the normal tibia.

W. Z. RIPLEY: Résumé of recent studies on the origins of European races. Presentation of a bibliography of the anthropology and ethnology of Europe.

D. A. SARGENT: Typical American students, illustrated by charts and statues.

G. W. FITZ: A new kymographion; a new chronoscope.

J. McKEEN CATTELL: Anthropometric instruments.

HUGO MÜNSTERBERG: Psychology and art.

MRS. C. LADD FRANKLIN: The new theory of the light sense.

WALTER HOUGH: Social organization and laws of the Moki Indians. Korean Clan organization.

FREDERICK STARR: The Otomies of Mexico.

FRANK BAKER: The illusions of craniometry.

MATILDA C. STEVENSON: Zuni witchcraft.

CH. H. HENNING: Origin of the Confederacy of the Five Nations.

EDWARD S. MORSE: Is the stringed muiscal instrument pre-Columbian?

PAUL DU CHAILLU: The Norsemen, the conquerors of Britain.

DESIRE CHARNAY: The disappearance of the Cliff Dwellers.

SECTION I. *Economic Science and Statistics.*

B. E. FERNOW: The College of Forestry at Cornell University.

EDWARD ATKINSON: High wages in money, or what money will buy, the consequent of low cost of production. How to increase exports and how not. The inherent vice of legal tender.

S. EDWARD WARREN: Local life by local times. A study of competition and suburban prices.

CORA A. BENNESON: Executive discretion in the United States.

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Edward T. Peters: Examination of the theory of rent.

Henry Farquhar: The price of wool.

J. S. Willison: The transportation problem.

W. H. Hale: The formative period of a great city: a study of Greater New York.

John Hyde: Deviations from the normal in the annual rate of agricultural production.

H. T. Newcomb: Railway rates and competition.

C. A. Eaton: A sufficient social principle.

R. T. Colburn: Why not try a North American Zollverein?

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F. R. Rutter: The effect of tariff legislation on the importation and domestic production of sugar in the United States.

John Davidson: The ethical function of the economist. The development of colonial policy.

Mrs. Helen Davidson: The economic status of the nurse.

Marcus Benjamin: American Industrial Expositions, their purposes and benefits.

W. Felt: Scientific bookmaking.

W. R. Lazenby: A plea for manual and industrial training in horticulture.

Robert T. Hill: The economic possibilities of Cuba.

W. Lane O'Neill: On the United States' alleged policy of imperialism, so-called, and in connection therewith, some reasons for and against the proposed Anglo-Saxon alliance.

A. W. Campbell: The economic value of good roads.

S. Morley Wickett: The study of political economy in Canada.

C. C. James: The agricultural statistics of Ontario.

Thomas Southworth: Canadian forests and the paper industry.

Henry C. Bolton: A catalogue of scientific and technical periodicals, 1665 to 1885.

2. *British Association.*—The sixty-eighth meeting of the British Association for the Advancement of Science was held at Bristol from September 7 to 14: this is the third time the city has been thus honored. The meeting was thoroughly successful both in scientific results and in attendance, as recorded in the issues of *Nature* for Sept. 8 and following dates. The inaugural address, delivered by the President, Sir William Crookes, was largely devoted to a discussion of the probable food supply available in the future for the increasing population of the earth. After showing "that England and all civilized countries stand in deadly peril of not having enough to eat," the speaker indicated that some comfort could be found in various directions, particularly in the probable solution of the problem of obtaining nitrates for enriching exhausted soils from atmospheric nitrogen by electrical means. The address also included an interesting account of recent progress in the departments of physics and chemistry, to which the speaker had especially devoted himself.

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[FOURTH SERIES.]

ART. XXXV.—*Irregular Reflection*; by C. C. HUTCHINS.

IN photometric work it has been customary to assume the validity of Lambert's fundamental law of reflection; namely, the amount of light sent from one surface element f to another surface element m is proportional to

$$\frac{f \cdot m \cdot \cos s \cos v}{r^2},$$

where r is the line joining the two elements, and s and v are the angles made between r and the normals to the two elements. The truth of this law seems to be borne out by common experience. Thus a sheet of paper illuminated by perpendicular rays,—the globe of a student lamp, seems equally illuminated at all points of view, and other examples of a similar nature will readily suggest themselves.

This seeming agreement of fact with theory, however, does not do away with the desirability of an experimental investigation of the subject.

The matter has been dealt with for certain bodies, for instance the moon, photometrically by Zöllner and others, and its total radiant energy with respect to phase has been measured by Ross and Very; but the measurement in the laboratory of the total reflection of bodies at different angles of reflection is, as far as can be learned, new.

Suppose a plane surface of small dimensions illuminated by perpendicular rays and seen at a fixed distance at different angles; then the effect produced at the point of view will be proportioned to the cosine of the angle of reflection, provided the plane surface is without specular reflection.

The ideal surface imagined above, however, does not exist in fact; for to be without specular reflection it must possess irregularities large in comparison with the dimensions of the waves of the illuminating ray, and just in proportion as these irregularities are greater does the surface depart from a true plane.

It will furthermore be seen that a surface, say of very fine grain, might show specular reflection for long waves and irregular reflection for short ones, and consequently, a different distribution of reflected energy according to the length of waves in the illuminating ray. Consequently the results of any investigation of the matter should be given either for definite wave lengths or for the total reflected energy.

In the following experiments surfaces of various character have been employed, in order to get an idea of the manner of the reflection as determined by the character of the reflecting surface, and at the same time to see how widely the reflection may depart from and how closely it may approximate to theory.

Apparatus.

A divided brass circle has at its center a fixed pin, about which revolves an arm 60^{cm} long, and having an index for reading off the angles. The outer end of the arm has supports for holding the thermograph, which thereby points always to the center of the circle.

The central pin is drilled for the reception of an upright wire, which latter carries the body under experiment. A number of discs of sheet zinc 4^{cm} in diameter were provided, and upon these could be spread any body in powder form, by first coating the disc with gum-water. Solid bodies were worked into discs 4^{cm} in diameter and secured to wires.

Sunlight is brought into the room by a heliostat having a mirror silvered upon its first surface, and the beam of light is directed upon the body at the center of the circle, and set to receive the beam perpendicularly. An appropriate shutter is introduced into the path of the beam, and can be operated by the observer at the galvanometer by pulling a cord. The thermograph is the same instrument that has been employed in former heat investigations and will be found described in this Journal for May, 1892.

The controlling magnet of the galvanometer has been in most cases adjusted so as to give the needle a period of about six seconds.

The method of observation is as follows: The body under investigation and the beam of sunlight being adjusted as above mentioned and the shutter closed, the observer draws the cord

and opens the shutter during the first swing of the needle. The deflection being recorded, the arm is moved by intervals of 10° and the deflection corresponding to each angle of reflection thus obtained. The numbers so obtained will be proportional to the amounts of energy reflected at the various angles. To make them comparable with the theoretical values these numbers should be multiplied by such a factor as will reduce the galvanometer reading for zero degrees reflection to one, or one hundred. As it is impossible to obtain a reading at zero, and as exterpolation is uncertain, it is better to employ such a factor as will make the reading at ten degrees, the smallest angle of observation, equal to the cosine of that angle. These reduced readings may then be plotted for comparison along with the curve whose equation is $y = \cos x$. A glance will then show to what extent a body in its reflection departs from or approaches to Lambert's law.

Among the bodies tested, those that approach most nearly to a smooth surface without specular reflection are a carefully prepared surface of plaster of Paris and a surface of magnesium oxide, made by coating a zinc disc by holding it above burn ing magnesium ribbon.

The following table gives the galvanometer deflections for these bodies, and the same reduced as above described.

	Plaster.		Magnesia.	
Angles.	Gal.	Reduced.	Gal.	Reduced.
10°	258	98·5	190	98·5
20	249	95·0	181	93·6
30	224	85·5	169	87·6
40	197	75·2	148	76·4
50	170	64·9	121	62·7
60	119	45·4	81·2	42·0
70	71·7	27·4	58·2	30·1
80	24·0	9·16	21·0	10·9
90	0·00	0·00	0·00	0·00

It will be seen that the curves plotted from these observations (Figs. 1, 2) follow the sine curve very closely, and the direction in which they depart is exactly what we should expect, assuming the validity of the fundamental law. The amount of reflection is a little too great, according to the observations, for small angles of reflection. Now if there were any specular reflection it would be most manifest at the angle of reflection nearest the angle of incidence, and, moreover, it will be immediately shown that irregularities of surface also have the effect of making the amount of reflection greater at small angles of reflection than is demanded by the law.

A disc of white filter paper and a plaster disc cut with a graver into fine vertical furrows were substituted for the smooth surfaces with the following results:

	Paper.		Furrowed plaster.	
	Gal.	Reduced.	Gal.	Reduced.
10°	151	98·5	217	98·5
20	134	87·6	193	87·2
30	117	76·3	169	76·7
40	96·2	62·9	148	67·3
50	80·5	52·6	121	54·9
60	58·7	38·4	88·0	40·0
70	37·5	24·5	59·5	27·0
80	16·0	10·5	30·7	13·9

The curves derived from these observations (Figs. 3, 4) show a wide departure from those of the plane surfaces and are not even approximately coincident with the sine curve. The observations are, however, in exact accordance with the results derived

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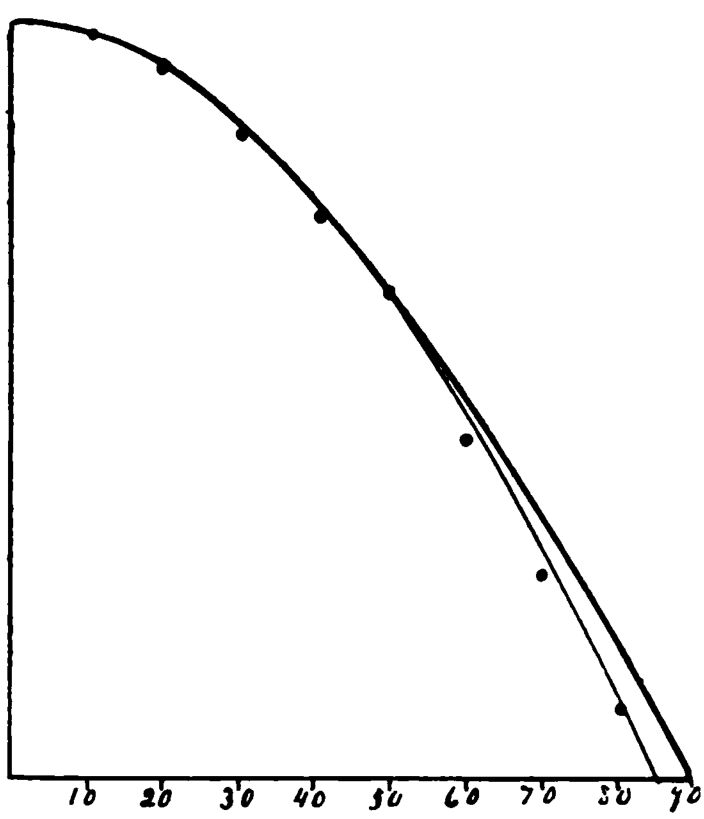

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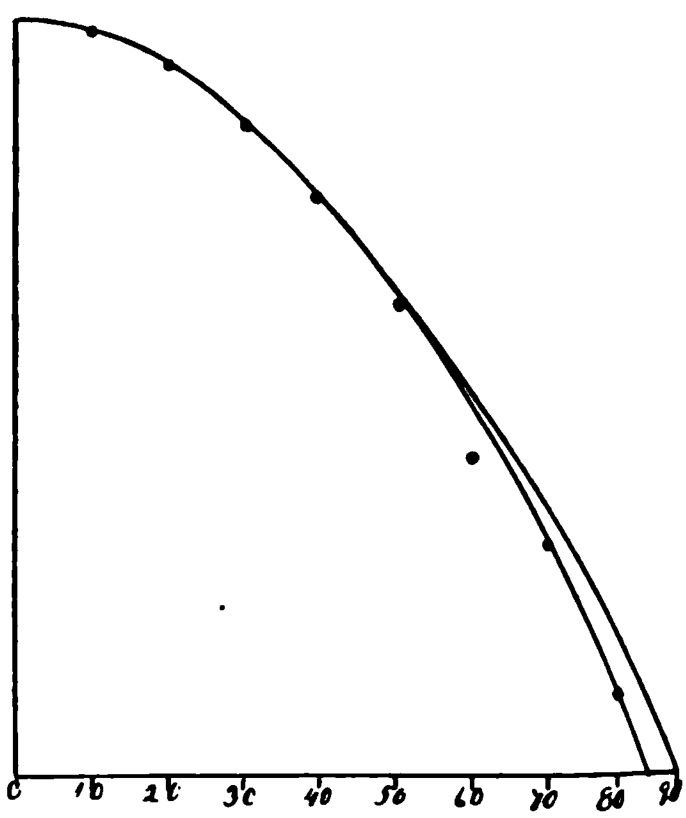

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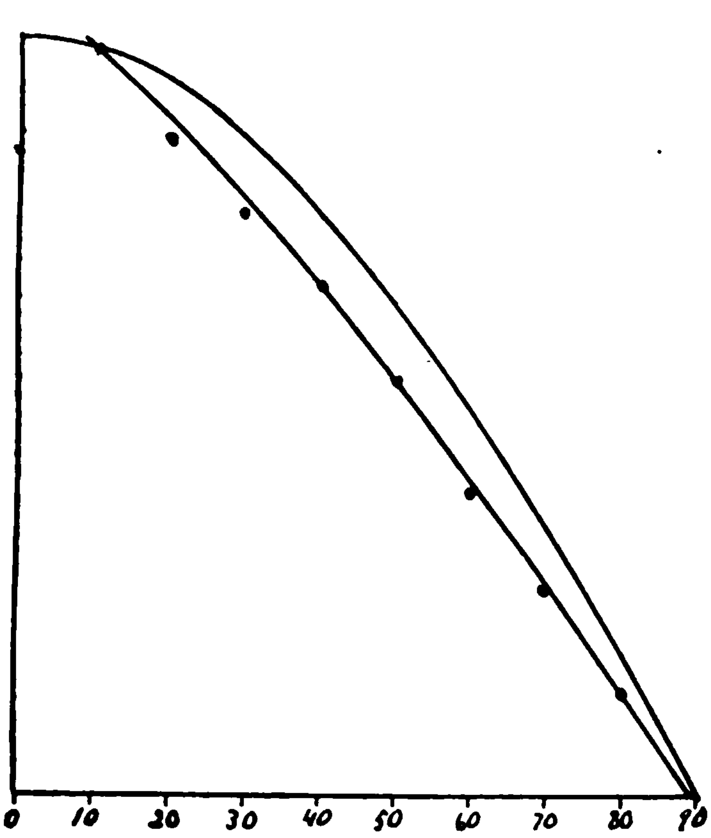

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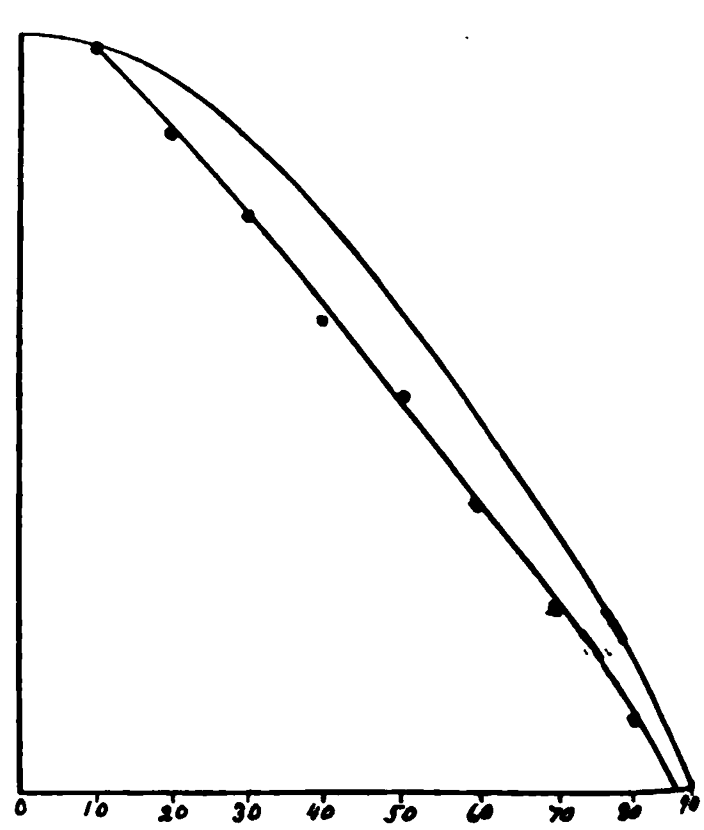

by Arthur Searle* from the analytical study of the reflection of a furrowed cylinder. Other bodies of greater or less fineness of grain or powder illustrate the same fact. A few are here given.

	Clay.		Marble powd.		Lava.	
	Gal.	Red.	Gal.	Red.	Gal.	Red.
10°	100	98·5	130	98·5	94·2	98·5
20	86·5	85·0	124	93·6	83·5	87·3
30	80·5	79·1	107	81·4	69·3	72·4
40	75·2	73·9	94·3	71·4	63·6	66·5
50	58·5	57·5	76·5	58·0	53·6	56·0
60	45·7	44·9	62·5	47·4	43·6	45·6
70	30·8	28·2	39·0	29·6	28·3	29·6
80	16·0	15·7	17·5	13·3	16·4	17·1

The inference to be derived from these observations seems to be that the manner of reflection of any body is to be learned only from an experimental study of it.

Next after a plane the sphere is perhaps the surface possessing the most interest; a knowledge of its manner of reflection being of special importance in astronomy in problems relating to the light given by the planets and other bodies.

Lambert's formula for the reflection of a smooth sphere is $L = {}^1/_\pi\,(\sin v - u \cos v)$. The curve of this equation is represented in fig. 5, by the smooth continuous line. The phase angle at new moon is taken as 0° and the light at apposition equal to 100.

Phase angle.	Magnesia.	Lead.	Red clay.	Moon.
30°	3·00	4·24	12·6	
40	4·71			
50	7·52	7·46	18·2	
60	11·5			
70	17·0	13·3	26·7	
80	23·3			19·9
90	31·1	25·9	34·0	25·0
100	39·1			31·0
110	51·3	43·8	40·6	37·5
120	58·9			44·9
130	69·4	66·4	61·0	53·6
140	79·3			62·8
150	88·0	85·2	72·8	73·2
160	93·5			83·9
170	98·4	98·5	92·1	93·8
180	100	100	100	100

Substituting now for the flat surface a small carefully prepared sphere of magnesia obtained by smoking an ivory ball

* Phases of the Moon, American Academy of Arts and Sciences, 1884.

with the burning metal, we find that its reflection is very closely represented by Lambert's equation, departing slightly in the direction predicted by Searle for a furrowed cylinder.

The preceding table gives the observations upon the sphere of magnesia, a sphere prepared by painting an ivory ball with carbonate of lead, a sphere of reddish colored clay, and finally Very's results from his well known study of distribution of lunar heat with respect to phase.

In fig. 5 the observations for the red clay sphere are represented by the dotted line, and Very's observations by the line

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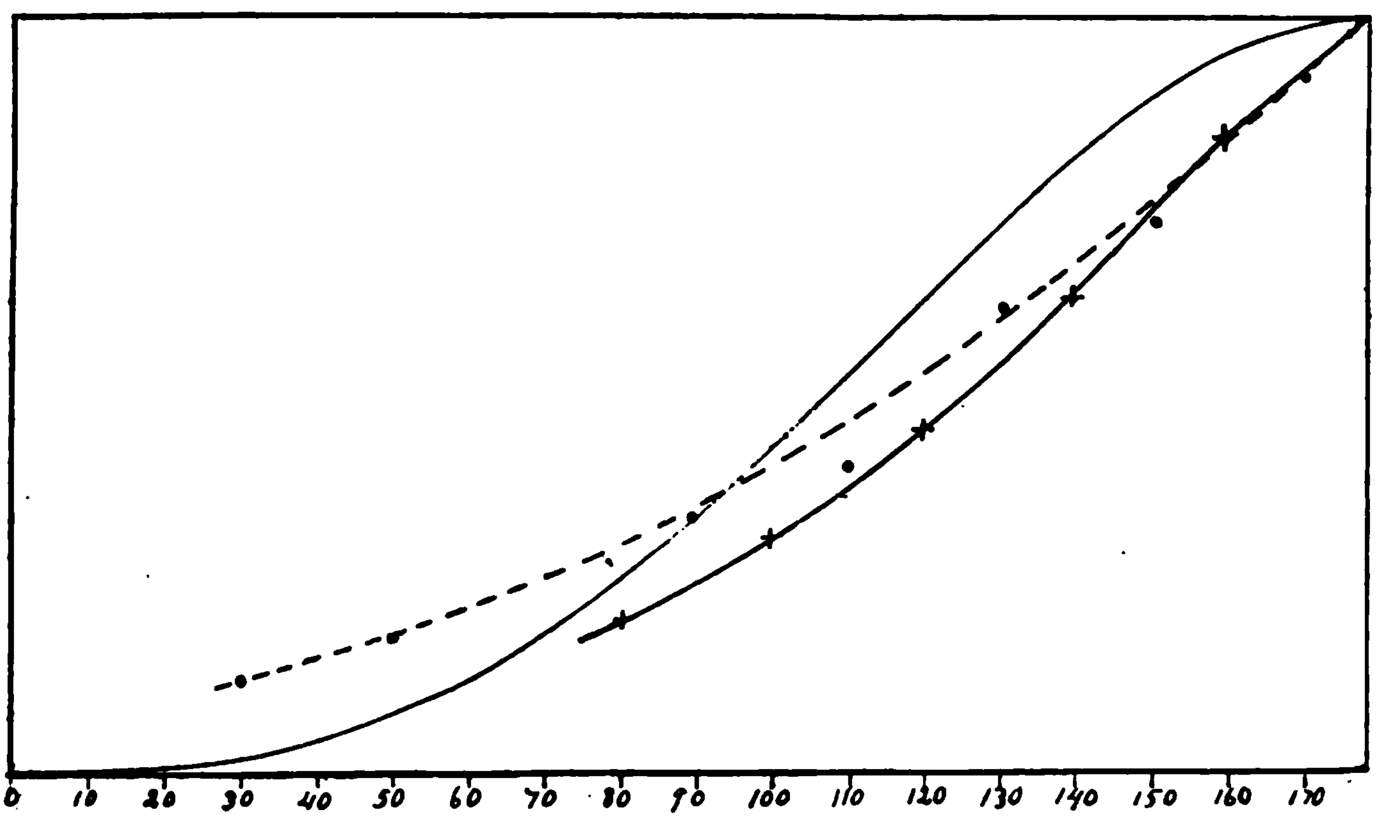


marked with crosses. Both depart widely from the theoretical curve. It will be seen that for small phase angles the reflections are too large for all bodies investigated, and although Very's observations extend only to 80°, yet judging from the direction of the curve at that point, the same would be found true for the moon. This may be due wholly or in part to specular reflection, for in the case of the sphere the smaller the phase angle the more would the specular reflection become manifest.

The result of these observations is to add emphasis to what was said above of the flat surface; that is, the manner of reflection of a body is largely determined by the character of its surface and is only to be determined by the study of that body individually.

Considerable interest attaches to the question whether the reflecting power or albedo of a body is the same when measured by the photometric method as when the total reflected energy is taken into account. The method of observation above described permits of the estimation of the albedo for

the total reflection. We must know what the galvanometer deflection would be provided the thermograph received direct sunlight. To this end a brass plate having a small hole at its center is put in the path of the sunbeam near the heliostat, and the galvanometer deflection produced by the sun so reduced is observed. We may calculate the deflection for the unreduced sun and the albedo as follows:

Let $L =$ distance of small hole to thermal junction.
$l =$ dist. of body under experiment to thermal junction.
$d =$ sun's apparent diameter.
$G =$ galvanometer deflection by reduced sun.
$g =$ " " " body.
$M =$ diameter of small hole.
$m =$ " " body.

Now on the supposition that the body in the form of a flat disc reflects in accordance with the sine law, and that m is not large in comparison with l, the whole interior of a hemisphere having the body at its center would be uniformally illuminated, and were the total reflection received by this hemisphere received by the thermograph the galvanometer deflection would be

$$\frac{2\pi l^2}{\pi\left(\frac{m}{2}\right)^2} \cdot g$$

The deflection by the unreduced sun would be

$$\frac{(L \sin d)^2}{M^2} \cdot G,$$

and consequently the albedo,

$$\frac{(L \sin d)^2 \left(\frac{m}{2}\right)^2}{2M^2 l^2} \cdot \frac{g}{G}$$

The following were the dimensions of the constants:

$L = 640^{cm}$
$l = 57{\cdot}5$
$d =$
$M = 0{\cdot}1567$
$m = 4{\cdot}00$

For present purposes d may also be considered constant, and the above reduces to $K \cdot \frac{g}{G}$, in which $\log K = 9{\cdot}9417$.

The annexed table gives the values of g and G for a few bodies and the resulting value of the albedo.

	G.	g.	Albedo.
Plaster	158	168	92·7
Magnesia	158	86·3	47·6
Paper	159	151	82·6
Green leaf, upper side	116	40·3	30·2
Green leaf, under side	116	50·6	38·0
Volcanic rock	192	60·2	27·4
Brown soil	192	69·7	31·7

The photometric value of the albedo of white paper is 68, with which the number found above agrees very well. The comparatively large values found for dark bodies like the soil are probably due in part to heat absorbed and re-radiated. The less the reflecting power of a body, the more prominent would this radiant part become.

The case of magnesia is rather peculiar; although it seems white to the eye as though reflecting all rays equally, it nevertheless absorbs a large portion of the longer waves.

Searles Physical Laboratory, Bowdoin College, July, 1898.

ART. XXXVI.—*Occurrence of Sperrylite in North Carolina;* by W. E. HIDDEN.

SPERRYLITE was first observed by the author at the new locality in North Carolina in September, 1894, but the quantity found was so minute that no announcement was then made.

The presence of this rare platinum arsenide has, however, been proved to be rather widespread in the immediate vicinity of the first discovery and its general occurrence in meagre amounts throughout the region seems now established.

It was found first at the mouth of the "Ned Wilson Branch" of Caler Fork, a prong of Cowee Creek, in Macon County, North Carolina, while the writer was testing some corundiferous gravel as to the possible presence of gold. The place is locally asserted to have yielded, many years ago, a sample of fine-grained gold to Robert Caler, the first white settler of the Cowee Valley.

The writer soon discovered some small grains of gold and by re-washing a rather large amount of gravel, that had been already washed and examined for corundum, a concentrate was obtained that yielded gold enough to weigh and to have assayed* and also the crystals which were later recognized as being sperrylite.

It was the microscopic examination of the particles of gold—in an endeavor to learn if they had traveled far, or originated locally—that led to the discovery of the associated sperrylite. Many hours of patient labor were expended, in the finding and complete separation of the minute crystals of sperrylite from the concentrate. This was largely composed of minute grains and crystals of monazite,† which were brilliant yellow and transparent; zircon, in colorless brilliant crystals and nodules; menaccanite, as very bright smooth black grains; rutile, as clear red highly polished particles, and gold as minute flat grains and as nuggets. It was noticed that the sperrylite occurred in nugget-like masses, as well as in the form of cubo-octahedrons and that many of the crystal edges were rounded (though not by abrasion). The luster of the sperrylite is nearly like that of mercury, but in some lights a color and appearance like that of dark sphalerite was observed. The crystals were entirely opaque even on very thin, broken edges. The occurrence in an old alluvial gravel, along with gold; the lack of any evidences of oxidation, or other chem-

* Its "fineness" was 0·901, which is much above the usual average of North Carolina gold.

† This monazite has been proved to contain only 0·03 per cent ThO_2.

ical alteration; the apparent great density (as shown by its remaining with the gold when "panned-out" from the gravel with water and also when a gentle air-blast was used in the final isolation of the denser and larger particles from the heavier concentrates) and its brittleness; all pointed to its being a member of the laurite-sperrylite group, and this supposition was sustained by chemical tests and measurement of the crystals.

The total "find" was sent to Professor S. L. Penfield, who very kindly reported the results of his careful examination as follows (quotation from a letter dated Oct. 22, 1894): "I have tested the little crystals you sent and found distinct arsenic and platinum reactions. Have measured one crystal and obtained isometric angles." "My tests were as follows: The crystals [55], weighing in all 0·0019 gram, were roasted in an open tube and yielded a volatile sublimate of arsenious oxide, crystallizing in isometric octahedrons. The residue, after roasting, had the color of platinum and when dissolved in nitro-hydrochloric acid gave a yellow solution, which when tested with potassium chloride yielded isometric octahedrons of potassium platinic-chloride."

"The crystals showed the combination of cube and octahedron with usually about equal development of the two forms. One of the largest crystals was about 0·2^{mm} in diameter and was measured with the following results:"

		Measured.	Calculated.
$111 \wedge 100$	=	54° 18′	54° 44′
$111 \wedge 010$	=	54 49	"
$111 \wedge 001$	=	54 47	"
$\bar{1}11 \wedge 001$	=	54 45	"
$111 \wedge \bar{1}00$	=	125 19	125 16
$111 \wedge 1\bar{1}1$	=	70 25	70 32

"The foregoing angles indicate that the crystals are isometric like the sperrylite from the Algoma district, near Sudbury, Canada."

No sperrylite or gold has as yet been found *in situ* or in bowlders in the Cowee district, but the abundance of hornblendic-gneiss and the constant occurrences in it of seams and disseminated pyrite, chalcopyrite, nickeliferous-pyrrhotite and sphalerite, indicate that sperrylite can now be searched for, with confidence, all along the pyritous belt of western North Carolina, or in similar Sudbury-like situations.

Pyrite found in cavities *in situ*, one-half a mile east (up-creek) of the "Ned Wilson Branch," had the exact habit of the sperrylite crystals found in the gravel below.

Sperrylite has been found at four new places in the Cowee Valley up to the present time, namely, at two gravel excavations just west of the locality above described and at two similar places east, but all are along the bed of the "Caler Fork" of Cowee Creek and are embraced within a distance of one and one-half miles.

Another new locality of sperrylite and one of very decided promise was found last summer two miles southwest, in a small valley, but this occurrence will be duly described in an article soon to appear in this Journal descriptive of the minerals of "Mason's Branch" in this same county.

In conclusion the author wishes to express his thanks to Professor Penfield for his kindness in making the micro-chemical and crystallographic examinations which were so essential to the positive identification of this rare and interesting mineral.

ART. XXXVII.—*Description of a Fauna found in the Devonian Black Shale of Eastern Kentucky;** by GEORGE H. GIRTY.

FOSSILS have been found at so few localities in the Devonian black shale of Ohio and the southern Appalachian region generally, and those constituting so limited a fauna,† that any additional imformation in either particular should not be without interest.

The collections which furnish the subject-matter for this paper were made by M. R. Campbell and L. C. Glenn of the U. S. Geological Survey from two localities in eastern Kentucky, and in both instances come from near the base of the black Devonian shale.

The following lists show the fauna collected from these localities:

Oil springs on Lulbegrud Creek, two miles southeast of Indian Fields, Clark Co., Kentucky.

Lingula (*Lingulipora*) *Williamsana* n. sp.
Leiorhynchus quadricostatum Vanuxem.
Prioniodus armatus Hinde.
Sporangites Huronensis Dawson ?

Two miles southwest of Jeffersonville, Montgomery Co., Kentucky.

Lingula (*Lingulipora*) *Williamsana* n. sp.
Orbiculoidea sp.
Leiorhynchus quadricostatum Vanuxem.
Meristella cf. *Haskinsi* Hall.
Plethospira socialis n. sp.
Sporangites Huronensis Dawson ?

Further collections at these localities would probably bring to light a much more extensive fauna than these lists contain. Indeed, Linney mentions, besides the remains of plants and fishes, a species of Bellerophon and an Orthoceras. These invertebrates, he says, are replaced by pyrites, as is the case with the gasteropod shell described below. Leiorhynchus, however, as it appears in my collection, is a mere impression, though the shell substance of Meristella seems to be retained, while Lingula, as is usual, presents dark, shining phosphatic surfaces.

* Published with the permission of the Director of the U. S. Geological Survey.

† In the Genesee of New York State a much more abundant fauna is known. Clarke mentions forty-three species (six being plants) from the Genesee rocks of Ontario Co. (Bull. U. S Geol. Surv., No. 16, p. 33), which with twelve species identified by other authors from the State of New York, makes a total of fifty-five.

A more detailed description of the character and occurrence of the black shale in Clark and Montgomery counties can be found in the Geol. Surv. Kentucky, Report on the Geology of Clark and Montgomery counties, by W. M. Linney, pp. 33, 81. It has here thinned out to a little more than a hundred feet and rests upon a limestone, said to be the Corniferous, which itself has a thickness of only seven feet.

The age of the Devonian black shale has generally been accredited as that of the Genesee shale of New York,* and the

* At first, as is well known, the black shale of the central States was correlated with the Marcellus shale of New York (Hall, 1842, this Journal, vol. xlii, pp. 57, 62; Hall, 1843, Trans. Ass. Am. Geol. and Nat., vol. i, 1840–1842, pp. 272, 280, 289; Hall, 1843, Geology of New York, pt. 4, Survey of Fourth Geol. District, p. 519; Rogers, 1843, this Journal, vol. xlv, pp. 161, 162; Hall, 1845, Boston Jour. Nat. Hist., vol. v, No. 1, p. 10; Hall (somewhat doubtfully). 1862, Fifteen Ann. Rep. New York State Cab. Nat. Hist., p. 81); but in 1847 de Verneuil published his paper on the parallelism of the Paleozoic deposits of North America with those of Europe (Bull. Geol. Soc. France (2), vol. iv, pt. 1, pp. 646–710) in which he showed that the formation in question was the equivalent of the Genesee.† and since that time geologists have, for the most part, sanctioned this correlation. Hall published a condensed and annoted translation of this work (this Journal, vol. v, 1848, pp. 176–183, 359–370, and vol. vii, 1849, pp. 45–51, pp. 218–231) in which as coming from de Verneuil are found on p. 182 (footnote, vol. 5) an intimation and on p. 370 (vol. vii) a distinct statement of the correlation of the Black Slate with the Genesee, a conclusion of which in a footnote on p. 182 (vol. v) the translation appears to concede the correctness. Later, however, he recedes from this position, for the black shale at Rockford, Indiana, he again refers to the age of the Marcellus shale (Thirteenth Ann. Rep. New York State Cab. Nat. Hist., 1860, pp. 95, 96, 112). Meek and Worthen (this Journal, vol. xxxii, 1861, pp. 167–177) show that the Goniatite bed at this locality referred to by Hall, instead of being Marcellus, really belongs to the Carboniferous era. They claim (p. 172) that the black slate in Illinois rests upon well marked Hamilton beds and cannot therefore be equivalent to the Marcellus shale, being most probably better correlated with the Genesee as held by de Verneuil. Similarly Meek has shown that the black bituminous shale of Athabasca and Clear Water, which rests upon a limestone stratum correlated by him with the Hamilton limestone, represents the Genesee instead of the Marcellus shale, to which horizon it is referred by Sir John Richardson and Mr. Isbister. He concludes that the dark, bituminous shale or slate known as the black shale of the Western States, which is rather extensively developed in southern Indiana, and portions of Illinois, Kentucky, Tennessee, and some of the Western and Southern States, holds "exactly the same position with relation to the Hamilton beds as the Clear Water and Athabasca shales" and is equivalent to the Genesee shale of New York (Trans. Chicago Acad. Sci., vol. i, pt. 1, 1867, p. 65 and footnote). Similarly in Ohio (Rep. Geol. Surv. Ohio, vol. i; Geol. and Pal. pt. 1, Geol. 1873, p. 154) the Huron shale is shown by Newberry to be underlaid by Hamilton shales. He cites the Huron shale from Canada, New York, Pennsylvania, Kentucky, Tennessee, Michigan and Indiana, and correlates it with the Genesee and overlying Gardeau shale of New York. In "Indiana, Dep. Geol. and Nat. Resources, Twenty-first Ann. Rep., 1896, p. 109," I find a chapter headed "Some notes on the Black slate or

† Even before this Owen thought that the balance of probabilities was in favor of correlating the black shale with the Genesee (this Journal, vol. iii, 1847, p. 72), while toward the same conclusion tend Yandall and Shumard (Contributions to the Geology of Kentucky, Louisville, 1847, p. 16), who identify some Lingulas and Orbiculoideas from the Black Slate of Indiana and Kentucky as *Schizobolus concentricus*, *Lingula spatulata* and *Orbiculoidea Lodensis*, all three described from the Genesee shale.

evidence here available indicates at least that the base of the formation in this region probably belongs to the Genesee period. The peculiar punctate Lingula which I have called *L. Williamsana* occurs in the typical Genesee, but is not known to me elsewhere,* and *Leiorhynchus quadricostatum* also is a Genesee species. *Meristella Haskinsi* was described from rocks of the Hamilton period, but my identification, owing partly to insufficient material, is only qualified. *Plethospira socialis*, while it has its closest allies in the early Devonian, is nevertheless probably a new species with little weight as evidence, and *Prioniodus armatus* together with *Sporangites Huronensis?*, which I believe to be correctly identified, are of supposedly Genesee age. On the whole, it is safe to say that the base of the Devonian black shale at these points was about contemporaneous with the middle Devonian of New York, and can probably be correlated with the Genesee shale of that State.

Genesee shale of New Albany, Indiana," clearly accepting Meek's correlation above referred to, while Hall and Clarke (Geol. Surv. New York, Pal., vol. viii, pt. 1. desc. pl. 4K. fig. 6) cite Lingula sp. (*L. Williamsana* of this paper) occurring in the black shale at Vanceburg, Kentucky, as from the Genesee horizon. These instances are enough, though others might be cited, to support the statement that the tendency among recent workers has been to concede the correlation of the black shale of the Central States with the Genesee shale of New York. And as a general statement this seems to be correct, especially when referring to the basal portion of the formation, and where, as is the case in a considerable portion of the region named, it rests upon strata of recognized Hamilton age. However, Newberry (l. c.) speaks of finding Portage fossils in the upper part of the Huron shale in Ohio (*Clymenia? complanata*, *Chonetes speciosa*, *Orthoceras aciculum*, *Leiorhynchus quadricostatum*. The last named species is characteristically Genesee, and I am at a loss to know what form is indicated by *Chonetes? speciosa*.) Williams states (this Journal, vol. iii, 1897, p. 398) that at Irvine, Kentucky, the black shale conditions continued well up into Carboniferous time, while in the vicinity of Big Stone Gap he finds the black shale resting upon a limestone full of Corniferous corals, from which he reasons that the beginning of the black shales for this region can be fixed at a horizon "closely corresponding to that of the Marcellus shale in the New York section." This would make the black shale range, locally at least, or alternately, from the age of the Marcellus shale of New York to at least that of the Kinderhook group of Illinois. A similar conclusion has been stated by Shaler, who considers this formation in Kentucky and Tennessee to include everything from the top of the Oriskany to the Chemung (Geol. Surv. Kentucky, vol. iii, n. s., 18, p. 173). Lyon, however, writing in 1859 (Trans. St. Louis Acad. Sci., vol. i, p. 619–620) seems inclined on paleontologic evidence to refer the black shale of western Kentucky and Tennessee to the Lower Carboniferous rather than the Devonian, but this I believe to be due to a misapprehension on his part of the real position of the Goniatite beds at Rockford, Indiana, as included in, instead of situated above, the black shale, as is in fact the case.

*In a recent letter from Prof. J. M. Clark in relation to the Lingulas of the Genesee shale he speaks of observing Lingulas of elongate and slender spatulate shape in the higher layers of black shale which appear after the introduction of the normal Portage fauna, and adds that these black shales above the Genesee horizon are often confounded with true Genesee. It may be that our specimens of *L. Williamsana* from Seneca Lake are from this horizon, i. e., later than the Genesee, but both an impunctate Lingula which I identify as *L. spatulata* and a punctate one which seems to be *L. Williamsana* occur in the Styliola layer of the Genesee, so that the evidence of this species speaks for Genesee or a little later.

Lingulipora—new subgenus.

The character upon which this proposed subgenus of Lingula is based has not been unnoticed. Hall and Clarke in 1892 (Pal. New York, vol. viii, pt. 1, p. 17) mention it as occurring in the very species described below as new under the name of *L. Williamsana*, in which, indeed, it is a striking character of the shell. Similarly record is made in the same connection of "a finely preserved specimen of an undetermined species from the Waverly sandstone of Pierrepont, Ohio," which "shows strong punctæ, visible to the naked eye on the internal surface, where, according to the author above cited, the calcareous layers of the test are thickest." These authors are inclined to regard this punctation as an exaggeration of the microscopic canals which Gratiolet has described as occurring in the calcareous layers of the shell of *Lingula anatina* (Journal de Conchyliologie, 2nd ser., vol. viii, 1860, p. 59). The figure given by Hall and Clarke (after Davidson after Gratiolet) show the tenuous shell as consisting, in the instance given, of at least sixteen alternating layers of calcareous and corneous matter. Each one of these must accordingly have been very thin, and to find in such attenuated sheets punctæ of a size to be detected by the naked eye and which at the same time are, as peculiar to each corneous layer, discontinuous, while not at all impossible would be, I think improbable. In the type species *Lingula* (*Lingulipora*) *Williamsana* the punctæ are visible upon exfoliate surfaces, upon the inside and also upon the outside of the shell. There is nothing to lead to the supposition that they are not practically continuous through the shell, and it is my belief that they are so. With pores the size of those in *L. Williamsana* and with the laminæ as thin as they must be in a small shell like that, it would be expected that in exfoliated surfaces not only the punctæ of the shell layer so exposed would be visible, but also less distinctly those of the next punctate layer below showing through. This, however, does not seem to be the case.

A large number of Lingulas representing many species and many geological periods have been examined with a view to ascertain to what extent this character of punctation has been developed in the genus during Paleozoic time. It seems to be by no means a frequent character and to vary considerably in degree, from where it can be seen with the naked eye as described by Hall and Clarke, to where it is difficult to catch even with an ordinary hand lens. In point of range the character seems to be restricted to late Paleozoic time, and not to appear in all Linguloid shells even then. In the Lingulas of the earlier Paleozoic, just as in recent Lingulas, not the faintest trace of

punctation was observed with the simple microscope employed,* but about the middle of the Devonian punctate shells like *L. Williamsana* began to appear and continued through Lower Carboniferous time into the Coal Measures at least.

The shells in which this character has been observed are given below, but unfortunately it has not been possible to identify with certainty all the forms mentioned.

Lingula Williamsana n. sp. From the Devonian black shale near Indian Fields, Clark Co., Ky.; near Jeffersonville, Montgomery Co., Ky.; and at Berea, Ky.; and also from the Styliola layer of the Genesee at Bristol, Ontario Co., New York, where it is associated with *Lingula spatulata*, and from Seneca Lake, New York, in the Genesee.

Lingula sp. A fragment from the roof of coal No. 1, Seville, Ill.

Lingula Meeki Herrick. From the Cuyahoga shale of the Waverly group at Ritchfield, Summit Co., Ohio.

Lingula delia Hall? A form from the Chemung group at High Point, New York, much resembling in shape *L. delia* of the Hamilton series, but which may prove to belong to *L. scutella*. Also another unidentified Lingula from the Chemung of New York, possibly the same as the one just mentioned.

Finding in the same stratum and preserved in the same way two Lingulas like *L. spatulata* and *L. Williamsana*, the one apparently impunctate, the other very strongly punctate, leads to the conviction on one hand and the suspicion on the other that the difference is not due to difference of preservation and is more than one of degree, or, if only so, is sufficiently marked to have more than specific significance. This is especially true where the character is coupled, as in this case it appears to be, with a characteristic geologic range.

It is unfortunate that the muscular and visceral impressions of Lingulipora, as in most Linguloid shells, are unknown, but when ascertained it is probable that individuality in these particulars will be found correlated with its peculiar shell structure. It might be urged that inasmuch as in all known particulars except this one, Lingulipora is closely similar to Lingula, which is really so individual a type compared with most other Brachiopods of the same periods, it should not be separated from the latter even as a subgenus. On the other hand, this character (punctate shell structure) has been and would now be used as a diagnostic of full generic value in any other type of

* A single specimen identified as *L. curta* Conrad? from the Modiolopsis beds of the Trenton formation at Frankfort, Ky., has the semblance of being punctate, or at least finely pitted over portions of its surface, but I suspect this to be an effect of weathering, or to arise from some other adventitious cause.

brachiopod shell, and in view of the difficulty of getting at the true generic elements of these forms, and of the paucity of even specific characters, a structural peculiarity such as this should be given the same weight or even more than the same weight allowed in other instances. Therefore I believe that the rank of Lingulipora as a subgenus of Lingula is rather under than over-estimated.

Lingula (*Lingulipora*) *Williamsana* n. sp.

Figs. 6–6^c, p. 395.

Lingula spatulata (pars) Vanuxem.

Lingula sp. Hall and Clarke, 1892, Pal. New York, vol. iii, pt. 1, p. 17, pl. 4^k, fig. 8.

Shell small, elongate, subquadrate; length about 1½ the breadth. Sides nearly straight and parallel. Posterior end in the dorsal valve broadly rounded; more acute in the ventral valve. Anterior margin more or less straight, rounding gently to meet the sides. Surface ornamented with innumerable fine concentric lines with occasional faint varices of growth. The fine concentric striæ under a rather high magnifier (they can be only just distinguished with an ordinary hand lens) are seen to be rather wavy, but much less so than some other ornamented Lingulas (e. g. *L. melie*) and on the whole are comparatively simple and direct.

Shell substance strongly punctate and, for the size of the shell, rather coarsely so.

Length of a large individual 7^{mm}, width 4^{mm}, usually a trifle smaller than these measurements.

Locality and position. In the Devonian black shale at Berea, Ky.; near Vanceburg, Ky.; near Jefferson, Montgomery Co., Ky.; near Indian Fields, Clark Co., Ky.; White Creek Springs, Davidson Co., Tenn., and also in the Styliola layer of the Genesee shale at Bristol, Ontario Co., New York, where it is associated with *Lingula spatulata;* also from the same horizon at Seneca Lake, N. Y.

This species is evidently the same form figured by Hall and Clarke in the citation mentioned above, where attention is called to its punctate structure. The punctæ can often be seen as fine papillæ on the outside of the shell, among and interrupting the striæ, especially toward the front.

These authors cite *L. Williamsana* from near Vanceburg, Ky., and I have found it abundant in the black shale of Kentucky and Tennessee. Comparatively few Lingulas from the same general horizon in New York have passed through my hands, but there also it proved proportionally so plentiful that suspicions were aroused that this might after all be the real

L. spatulata. Such can scarcely be the case, and I have found both species associated in the Styliola layer of the Genesee. As mentioned in another place, Prof. J. M. Clarke informs me that in New York an elongate and slender spatulate Lingula occurs in the higher layers of the black shale which appear after the introduction of the normal Portage fauna, and that these black shales, especially in the western part of the State, are often confounded with the true Genesee. Some of the punctate Lingulas from New York which I have examined may possibly come from these beds, which would give the species a range through the Genesee and Portage horizons.

In Kentucky, *L. Williamsana* is considerably larger than *L. spatulata*, but the individuals which I have examined from New York are small. They can, however be distinguished by their punctate shell and difference in shape, being more square before and behind than *L. spatulata*, which, though subject to some variation in this regard, generally tapers more in both directions. The punctate shell structure, however, serves to distinguish them at a glance, especially in exfoliated specimens where in *L. Williamsana* the punctæ are a striking character, while the surface of *L. spatulata* is very smooth and shiny.

In point of shape, *L. Williamsana* closely resembles *L. punctata* Hall, but it is a much smaller shell, without the surface ornamentation of *L. punctata*, which in turn has not the punctate shell of *L. Williamsana.* It is also comparable in point of shape to *L. compta* Hall and Clarke of the Hamilton group, but that species also appears to be impunctate.

I take pleasure in naming this interesting species after Prof. H.S. Williams of Yale University, whose name is so honorably connected with the study of our Devonian faunas.

Associated with the above in large numbers is a minute Lingula whose specific relations have not been made out. They may be referable to *L. spatulata* or on the other hand be the young of *L. Williamsana.*

Meristella cf. *Haskinsi* Hall.

Meristella Haskinsi Hall, 1860. Thirteenth Rep. New York State Cab. Nat. Hist., p. 84.

Meristella Haskinsi Hall, 1867. Pal. New York, vol. iv, p. 303, pl. 50, figs. 1–12.

In the collection are found two imperfect specimens of Meristella, characterized by being probably subcircular in outline, rather strongly arched, and lacking both fold and sinus, or at least having them very faintly expressed. The size indicated by the specimens is from 18^{mm} to 23^{mm} in length. These characters are suggestive of *M. Haskinsi* of the Hamilton group of New York.

Locality and position. In the base of the Devonian black shale, supposed to be of the age of the Genesee shale of New York, near Jeffersonville, Montgomery Co., Kentucky.

Orbiculoidea sp.

Associated with the other fossils from the vicinity of Jeffersonville is a single dorsal valve of a small Orbiculoidea. It is nearly circular in shape, slightly truncate posteriorly and with the usual ornamentation of concentric lines. The diameter is $3\frac{1}{2}^{mm}$ and the excentric apex is situated near the truncate end, from which it is about 1^{mm} distant. In its size and other characters this shell much resembles *Orbiculoides minuta.*

Locality and position. At the base of the Devonian black shale, supposed to be of Genesee age, near Jeffersonville, Montgomery Co., Kentucky.

Leiorchynchus quadricostatum Vanuxem.

Fig. 5, p. 395.

Orthis quadricostata Vanuxem, 1842. Geol. New York, Rep. Third District, p. 168, fig. 2.

Leiorhynchus quadricostata Hall, 1867. Pal. New York, vol. iv, p. 357, pl. 56, figs. 44–49.

Much the same characters and the same range of variation are shown in the Kentucky representatives of this shell as in those from the typical localities. The fold and sinus usually contain 3 or 4 coarse plications, but sometimes also a larger number of finer ones. I have counted as high as 7 or 8. The sides are almost smooth, often showing two or three broad indistinct folds, but occasionally numerous finer but yet not strong radiating striæ.

I have referred this species to *L. quadricostatum* rather than to *L. mesicostale* because of the nearly constant obsolescence of the lateral plications.

Common in the strata from which collections were made.

Locality and position. At the base of the Devonian black shale, supposed to be of Genesee age, near Jeffersonville, Montgomery Co., Kentucky, and near Indian Fields, Clark Co., Kentucky.

PLETHOSPIRA Ulrich, 1897.

Plethospira socialis n. sp.

Figs. 1, 1ᵃ, 2, 2ᵃ, 3, 3ᵇ, p. 395.

Shell small and consisting of about three rapidly expanding volutions. The spire is low and small, the final whorl particularly large. Underneath, the shell is concave, and while most

specimens seem to show a broad open umbilicus, a single individual contains evidence of this opening having been closed by a deposit from the inner lip. Volutions regularly rounded, with a nearly circular transverse section.

Surface with revolving lines or ridges, ornamented only by striæ of growth which are regularly arranged. Band broad (nearly $1\frac{1}{2}^{mm}$), slightly elongated, concave, peripheral, and only about 6^{mm} or less in length, distinctly bounded above, below, and behind by a raised line. The striæ above the band bend backward to meet it, and likewise those beneath, very strongly so. The striæ upon the band also are rather strongly flexed backward. Just behind the rounded end of the band the striæ also seem to cease and the shell appears to be perfectly smooth, but the striæ, without however the band, sometimes reappear again upon the earlier volutions, especially it seems where protected in some way by the shape of the shell. This loss of surface ornamentation just before entering upon the banded stage is probably due to erosion, but at the same time the condition appears to be a persistent one. Diameter 7^{mm}, height 7^{mm}.

Locality and position. At the base of the Devonian black shale, supposed to be of the Genesee age, near Jeffersonville, Montgomery Co., Kentucky.

The specimens, of which quite a number have been collected, show great uniformity in size, and other characters lead to the conclusion that the type is a constant and normal one. The small size in conjunction with the short duration of the banded period, however, suggest that the collection may represent a sort of colony of immature individuals.

I do not know of any species of the same geologic age with which comparison may be made, but it has occurred to me that we may have here young examples of *Pleurotomaria plena** or *P. arata*† of the Upper Helderberg group or of *P. rugulata*‡ of the Goniatite limestone. *Plethospira socialis* certainly has not the ornamentation of *P. arata* and has a lower spire. Similarly it seems to be a smaller species than even young three-whorled examples of *P. plena*, and with a lower spire, though otherwise strongly suggesting Hall's species. *P. rugulata* in size and other characters seems more closely related than perhaps even *P. plena*, but even it is larger and proportionately higher.

Although originally described from the Marcellus shales, *P. rugulata* has also been identified by Clark from rocks of the Genesee period (Bull. U. S. Geol. Surv., No. 16, pp. 23, 33).

* Geol. Surv. New York, vol. v, pt. 2, 1879, p. 66, pl. 17, figs. 11, 12, 13.
† Ibidem, p. 64, pl. 17, figs. 1–8.
‡ Ibidem, p. 75, pl. 20, figs. 1–7.

Prioniodus armatus Hinde.

Fig. 4, p. 395.

Prioniodus armatus Hinde, 1879. Quart. Geol. Soc. London, vol. xxxv, p. 360, pl. 15, figs. 20, 21.

A single Conodont answering in every particular to Hinde's description of *Prioniodus armatus* and very probably referable to that species. There is one large terminal main tooth and eight proximate smaller denticles, one of which is more or less adnate to the larger one. The latter extends almost twice as far above the basal portion, which is narrow and slightly curved, as the denticles, and is prolonged downward into a spur about as far as they are long. The main tooth is, of course, not only longer but also much stouter than the others. Its downward spur-like extension is mentioned by Hinde, but exists to a more marked degree in the specimen described than in either of those figured by him. The denticles also are more crowded together, more as in his fig. 20 than as in fig. 21. This species was originally described from the Genesee period from erratic boulders found near Port Stanley, Lake Erie, Ontario, and from the Genesee shale at North Evans, New York. So far as I am aware it is restricted to rocks of that age.

Locality and position. At the base of the Devonian black shale, supposed to belong to the Genesee period, near Indian Fields, Clark Co., Kentucky.

Sporangites Huronensis Dawson ?

Sporangites Huronensis Dawson, 1871. This Journal, III, i, p. 257.

Minute spore cases are plentifully distributed throughout the material examined. They seem to agree in every particular with authentic specimens of *Sporangites Huronensis* except for being a trifle smaller. This species was described from a black shale exposed at Kettle Point, which is supposed to represent the Genesee shale of New York.

I am indebted to Mr. David White of the U. S. Geological Survey for suggestions leading to the identification of this species.

Locality and position. From the base of the Devonian black shale, supposed to belong to the Genesee period, near Jeffersonville, Montgomery Co., Kentucky, also near Indian Fields, Clark Co., Kentucky.

Description of Figures.

Figs. 1–3. *Plethospira socialis* n. sp.

1. Side view of an average specimen showing limited banded and ornamented area.

1^a. Same seen from above.

2. Another specimen of the same species.

2^a. Side view of the same.

3. Superior view of another specimen.

3^a. Inferior view of the same showing the umbilicus apparently nearly closed.

3^b. Side view of the same.

Devonian black shale (Genesee period?) near Jeffersonville, Montgomery Co., Kentucky.

Fig. 4. *Prioniodus armatus* Hinde.

The only specimen observed. × 18.

Devonian black shale (Genesee period?) near Indian Fields, Clark Co., Kentucky.

Fig. 5. *Leiorhynchus quadricostatum* Vanuxem.

Devonian black shale (Genesee period?) near Jeffersonville, Montgomery Co., Kentucky.

Fig. 6. *Lingula (Lingulipora) Williamsana* n. sp.

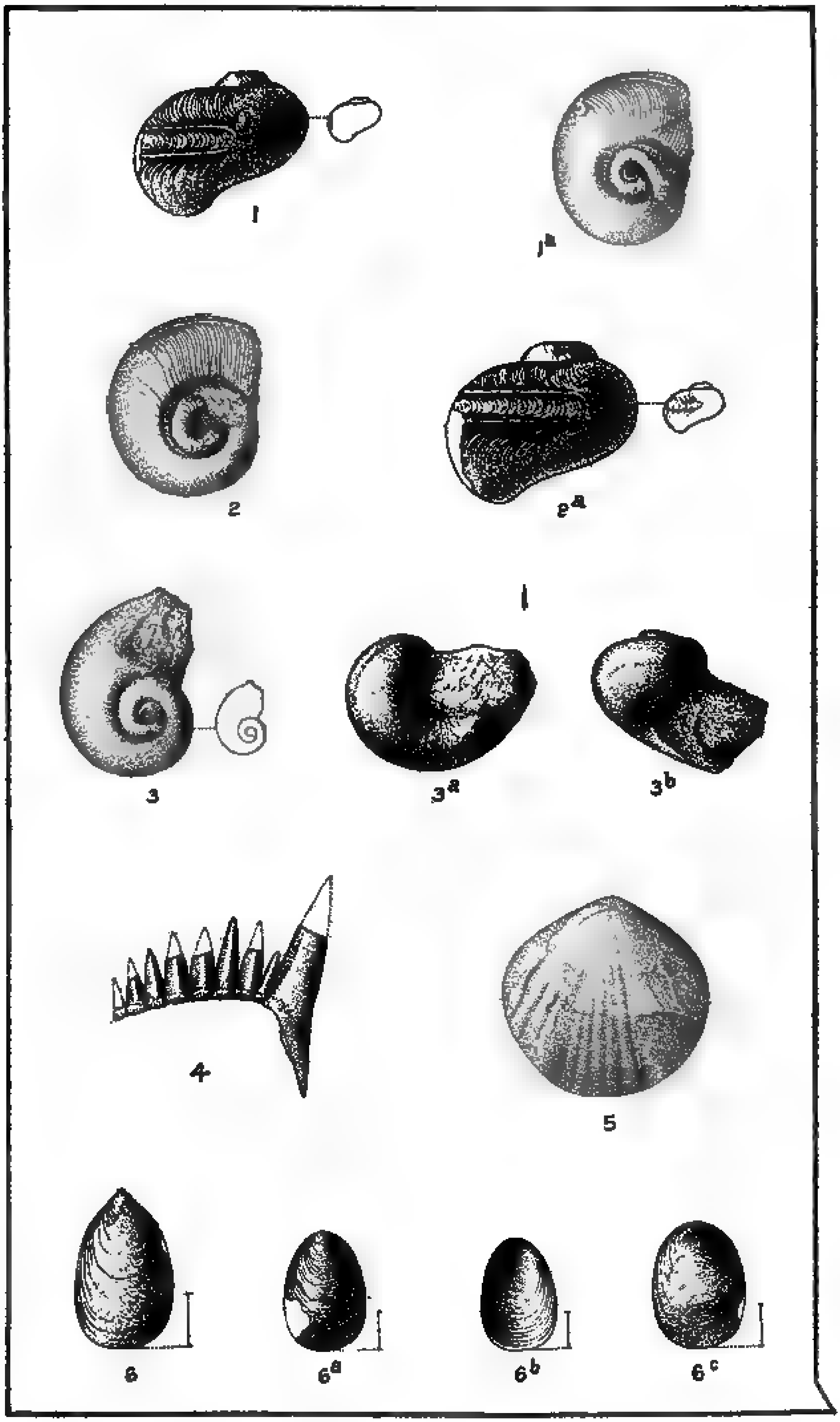
6. A rather large ventral valve, probably rendered somewhat too acuminate by distortion.

6^a. Ventral? valve.

6^b. Ventral? valve.

6^c. Dorsal valve.

Devonian black shale (Genesee period?) near Jeffersonville, Montgomery Co., Kentucky.


1
1a
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6a
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ART. XXXVIII.—*On the Separation of Nickel and Cobalt by Hydrochloric Acid;* by FRANKE STUART HAVENS.

[Contributions from the Kent Chemical Laboratory of Yale University.—LXXV.]

A QUANTITATIVE separation of nickel and cobalt by a process analogous to that published from this laboratory for the separation of aluminum and iron* has been put forward in a recent paper by E. Pinerùa.† The process may be described briefly as follows: The hydrous chlorides of nickel and cobalt (0·3–0·4 gms.) are dissolved in a little water and to the solution are added 10 to 12$^{cm^3}$ of aqueous hydrochloric acid and 10$^{cm^3}$ of ether, and the whole, contained in a little beaker surrounded with water and ice, is saturated with gaseous hydrochloric acid. The cobalt, which remains in solution, is decanted off and the yellow insoluble nickel chloride washed with a previously prepared solution of ether saturated with hydrochloric acid gas at a low temperature. The nickel is determined by known methods, preferably as the sulphate. The author claims very precise results for the process, but gives no experimental proof of his work. Previous to the appearance of this paper my experiments upon the solubility of nickel chloride in an ether-hydrochloric acid solution, such as used in our process for the separation of aluminum and iron, which is practically the same in proportions as that used by Pinerùa to effect precipitation, had shown that, while nickel chloride is somewhat insoluble in such a mixture, the degree of insolubility is not sufficient for a quantitative separation. Since the appearance of Pinerùa's work I have been over the ground again and have reached the same conclusions as before, as shown in the following experiments.

When a solution of 0·2 gm. of nickel chloride (free from iron and cobalt) in 7$^{cm^3}$ of aqueous hydrochloric acid, was saturated with hydrochloric acid gas at a temperature of $-2°$ C. (obtained by immersing the container in a mixture of ice and salt) no precipitation resulted. When, however an equal volume of ether was added and the whole was again saturated with hydrochloric acid gas a yellow precipitate formed, while the supernatent liquid still remained of a deep green color. The solution was filtered quickly through asbestos in a filter crucible, and the clear filtrate after evaporation with sulphuric acid was electrolyzed. The metallic deposit of 0·0020 gm. proved to be pure nickel; for when dissolved in nitric acid it gave no test for iron with potassium sulphocyanide or ferro-

* Gooch and Havens, this Journal, IV, ii, 416.
† Gaz. Chim. Ital., xxvii, 56.

cyanide, and neither the apple-green hydroxide nor the black sulphide, prepared by the usual methods, showed any trace of cobalt in the borax bead. It is obvious, therefore, that nickel chloride is not fully precipitated under these conditions and that the green color of the solution is due to nickel in solution and not to traces of iron, as Pinerùa has supposed.* A second experiment similar to the first showed a solubility of the nickel chloride represented by 0·0018 gm. of metallic nickel. It is evident, then, that the solubility of nickel chloride in this mixture of aqueous hydrochloric acid and ether thoroughly saturated with hydrochloric acid gas is not far from an amount represented by 0·0020 gm. of metallic nickel for every 14^{cm^3} of solution.

Still another experiment, in which nickel chloride representing 0·0020 gm. of metallic nickel was treated with 14^{cm^3} of the ether-hydrochloric acid solution and the whole saturated for one hour at a low temperature with hydrochloric acid gas without precipitation, showed the same thing.

When the nickel chloride remaining on the asbestos was washed with about 40^{cm^3} of a mixture of equal parts ether and aqueous hydrochloric acid saturated with hydrochloric acid gas, the washings evaporated with sulphuric acid and treated by the battery gave a deposit of metallic nickel weighing 0·0027 gm.—an amount proportionately less than that found in the filtrate proper.

Although employing a mixture of aqueous hydrochloric acid and ether saturated with gaseous hydrochloric acid for the precipitation, Pinerùa has advised the use of pure ether saturated with gaseous hydrochloric acid for the washing. In my experiments with such a mixture I find that in it the hydrous nickel chloride is practically insoluble and that 30^{cm^3} of the washings of the precipitated chloride with such a mixture gave no deposit of nickel by the battery. It seemed possible, therefore, that by reducing the water present to the lowest possible amount necessary to dissolve the chlorides to be treated the precipitation of the nickel might be made more complete. The experiments of the following table were made to put this idea to the test.

Solutions of the pure chlorides of nickel and cobalt, carefully purified and freed from other metals and each other, were, after conversion to the form of the sulphate, standardized by the battery. Weighed portions of these solutions were taken in a small beaker, evaporated to dryness, the dry salts dissolved in as little water as possible (about 1^{cm^3}), 10 to 15^{cm^3} of ether added, and the whole saturated with hydrochloric-acid gas, the beaker being meanwhile immersed in running water

* Loc. cit.

and cooled to about 15° C. When saturation was complete the precipitated chloride was caught on asbestos in a filter crucible, washed thoroughly with a previously saturated solution of ether, dissolved in water, evaporated with sulphuric acid and determined as metallic nickel by the battery. The cobalt in the filtrate was recovered by evaporation and electrolysis in like manner.

Experiments (1), (2) and (3) of the accompanying table show that by this process the nickel is thrown down quantitatively, and experiments (2) and (3) show that in the presence of a few milligrams of the cobalt salt the separation of a small amount of nickel is sharp. The residue of nickel in these experiments gave no test for cobalt with the borax bead. When, however, the cobalt is present to the amount of a few centigrams as in (4), (5) and (6), the precipitated nickel chloride, which forms a hard mass, includes the cobalt salt so that even a large quantity of washing solution (100^{cm^3} was used in experiment 6) cannot remove it.

	Nickel taken as the hydrous chloride.	Nickel found.	Error.	Cobalt taken as the hydrous chloride.	Cobalt found.	Error.
(1)	0·0068	0·0066	−0·0002	----	----	----
(2)	0·0090	0·0090	0·0000	0·0030	----	----
(3)	0·0090	0·0091	+0·0001	0·0123	0·0127	+0·0004
(4)	0·0469	0·0490	+0·0021	0·0700	----	----
(5)	0·0468	0·0503	+0·0035	0·0700	----	----
(6)	0·0472	0·0493	+0·0021	0·0700	----	----

From the experiments described it is obvious that the process as proposed by Pinerùa will not give a complete precipitation of the nickel chloride. Nickel chloride is, however, practically insoluble in pure ether saturated with hydrochloric acid gas and can be separated from small quantities of the soluble cobalt salt in that medium. In the presence of even a few centigrams of the cobalt chloride, however, the process is not practicable on account of the inclusion of the cobalt by the massive nickel chloride. It is possible that by repeated solutions and reprecipitations the nickel salt might be sufficiently freed from the cobalt, but the process must naturally be long and tedious.

In closing the author wishes to express his gratitude to Professor Gooch for kind suggestions.

ART. XXXIX.—*Contributions to Paleontology;* by F. A. LUCAS.

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1. *A New Crocodile from the Trias of Southern Utah.*

THE following genus and species is based upon the imperfect anterior portion of the lower mandible of a crocodile comparable in size with *Tomistoma* among living and *Thoracosaurus* among extinct species. The mandibular symphysis is long, though less than in *Tomistoma*, and includes a considerable portion of the splenial. The teeth are very close to one another, being separated by an extremely thin partition of bone, and the tooth row lies in a broad shallow groove. The teeth are set obliquely, raking decidedly outwards, and they are compressed from before backward, the antero-posterior diameter being slightly less than the transverse. The two anterior teeth are round in section and vastly larger than the others, the end of the jaw being expanded for their accommodation. The surface of the bone is somewhat pitted, there is a deep narrow groove along the side of the jaw and there is no notch for the upper canines and no depressions for the reception of any of the upper teeth. The genus is characterized by the antero-posterior compression of the teeth, their closeness to one another, and by the great size of the two anterior teeth. The name *Heterodontosuchus ganei* is proposed for the genus and species, the specific name being given in honor of the discoverer Mr. H. S. Gane, by whom it was transmitted to Mr. Whitman Cross of the U. S. Geological Survey. The specimen is from Clay Hill, Southern Utah, and is from the Trias at the top of No. 10 of the section given by J. S. Newberry on page 99 of the Report of the Macomb Expedition. The horizon is said by Mr. Cross to be the same as that from which teeth of a crocodile—probably a *Belodon*—and of a species of *Palæoctonus* were obtained by him in the Telluride, Rico, and La Plata Quadrangle of southwestern Colorado. Type No. 4136, U. S. Natl. Museum.

2. *A New Species of Dinictis (D. major).*

Among some specimens collected by Mr. N. H. Darton, of the U. S. Geological Survey, in 1897 is a species of *Dinictis* which proves to be new and the largest species of the genus yet discovered. The distinctive characters are the size of the animal, the feeble development of the mandibular flange for the protection of the upper canine, the robust character of the

feet and the presence of an ungual shield. The species, represented by the greater part of the skull, and many important portions of the skeleton, was the size of a small Puma, *Felis concolor*, but with much heavier feet. The upper canines are moderate, compressed, flattened on the inner face, with a slight keel on the antero-internal face and well-marked, serrated keel on the posterior edge. The anterior cusp is obsolete on the second, lower premolar, large on the third lower premolar. The mandible is rather deep, convex on the lower edge, and with the flange for the upper canine almost obsolete. The metapodials are stout, those of the hind feet especially so, being a trifle heavier, though slightly shorter, than the corresponding bones in a jaguar, *Felis onca*. The ungual phalanges have a well-developed shield. Some of the principal measurements are as follows:

Length of femur	·230
Articular breadth of femur	·042
Length of tibia—a little shortened	·180
Length of third metatarsal	·070
" " upper molar series	·054
" " lower " "	·065
" " " " " in *Dinictis felina*	·052
" " " " " in *Dinictis bombifrons*	·055

The name of *Dinictis major* is proposed for this species on account of its size.

The specimen was obtained by Mr. N. H. Darton in the massive sand at Bird Cage Gap, Bad Lands of Western Nebraska. Type No. 3957, U. S. Natl. Museum.

ART. XL.—*The Value of Type Specimens and Importance of their Preservation;* * by O. C. MARSH.

IN the present state of Natural Science, there are too many obstacles in the path of the original investigator. That this is the case in the study of Botany, we may well believe, as authorities of that Science have frequently placed the fact on record. It is certainly true that everyone who does original work in systematic Zoology, either among the living or extinct forms, meets many difficulties at the start in endeavoring to ascertain what others have done before him. The literature of the subject is often discouraging from its extent, and especially from its uncertainty. If the work in hand requires the comparison of type specimens, the difficulties greatly increase, and often prevent definite conclusions. The type will frequently be found the most important element in the problem, far more so than the literature, however extensive. This is more especially true among the extinct vertebrates, with which the present communication mainly deals.

(1) *The Value of Type Specimens.*

The value of a type depends first of all upon whether it is a characteristic specimen, worthy of being the representative of a new group of individuals. Without this distinctive quality, its importance is greatly diminished. If, for example, the specimen first described is immature, its essential features may thus be obscured, and its value as a type much diminished. On the other hand, a very old animal may be uncharacteristic. The teeth of a mammal, for instance, may be worn down or even lost, so as to make the normal dentition uncertain. This is true of recent forms, but is more important if the type belongs to an extinct fauna, as then the chance of duplicating it is much less.

The value of a type specimen again may depend largely upon its completeness. Among the invertebrates, especially those now living, types are usually complete enough to show the more important features. This, however, is far from being the case among extinct forms, particularly from the older formations, and the records of Paleontology are burdened with the names of many fragmentary fossils, types of species practically unknown.

* Read before Section B, International Congress of Zoology, Cambridge, England, August 23, 1898.

Among the vertebrates of the past, the case is much more serious, and here especially reform in methods is a pressing necessity. From the nature of the case, the older extinct forms are usually represented by fragmentary remains, the investigation of which is one of the most difficult problems offered to natural science. A single tooth or a vertebra may be the first specimen brought to light in a new region, and thus become the sole representative of a supposed new form. The next explorer may find more perfect fragments of the same or similar forms, and add new names to the category. A third investigator, with better opportunities and more knowledge, may perhaps secure entire skulls or even skeletons from the same horizon, and thus lay a sure foundation for a knowledge of the fauna.

As the number of described forms increases, the necessity of a direct comparison of types becomes imperative, and the comparative value of each type specimen is thus brought into notice. It will then frequently be found that not a few are uncharacteristic, while others are too incomplete to disclose their own essential features, and hence of little aid in indicating the affinities of forms found with them.

Type specimens that do not show characteristic features are, of course, of little value to science, and many such prove a delusion and a snare to the investigator, however faithfully he may endeavor to study them. The imperfect types require still more labor to decipher them. Not a few specimens to-day are types, for the simple reason that they are imperfect. If they had been entire when described, their true nature would have been recognized, and much confusion in nomenclature have been avoided. The chance preservation of some marked features may, indeed, give a hint as to what the whole specimen once was, but too often a suggestion only is thus offered, while the real nature of such types must always remain in doubt.

A type in Paleontology should consist of the remains of a single individual, and this should stand as the original representative of the name given. A second specimen, or even more, may be used later to supplement the first, but not to supplant it. This, however, has been done by some authors, with the natural result of causing endless confusion in the nomenclature.

The Selection of Type Specimens.

The descriptions in Paleontology are too often descriptive only, and not comparative. This, if well done, is preferable to long academic discussions in regard to the affinities of a

specimen of which the main characters are not known, or not placed on record. A vertebra of a reptile or the tooth of a mammal, if perfect and characteristic, may form a type that will be distinctive enough for the present requirements of the investigator. What the future may demand, will depend upon the advance of knowledge in that branch of science.

In the choice of specimens worthy of being types, I can only suggest a course that seems to me the proper one. I believe experience has already shown that to make types of incomplete or uncharacteristic specimens is seldom of permanent advantage to an author, and almost always a lasting injury to the branch of science he represents. There are more good specimens waiting to be found than any naturalist can possibly describe, and one such specimen is worth many of inferior grade.

I may perhaps be permitted to mention, in this connection, my own experience in the matter of type specimens. As a student in Germany, years ago, I had my attention called particularly to this subject, and was then strongly impressed with the importance of using only good specimens for first descriptions. This rule I have endeavored to follow. My researches, especially in western North America, have resulted in the discovery of more than one thousand new species of extinct vertebrates, and of these I have described about five hundred. Had I been satisfied to use inferior specimens as types, I might have increased the number by one-half at least.

No small part of the present literature of the paleontology of vertebrates is based on names applied to fragments, and a long period of more accurate work will be required before these can be rejected or incorporated into the digested knowledge of the subject. I recall one collection of types of extinct vertebrates, published in a single volume, and near a hundred in number, the greater part of which are uncharacteristic fragments, well fitted to burden science for all time with a legacy of uncertainty and doubt. Such work is a positive discouragement to all future investigators in the same field, and its value to science may well be questioned.

The necessity of greater care in selecting type specimens, in Paleontology, at least, needs no argument to any student of the science who has done sufficient original work to appreciate the increasing difficulties of accurate investigation. To those who have had less experience, a word of warning, I trust, will not be in vain.

(2) *The Preservation of Type Specimens.*

The careful preservation of their own type specimens is a sacred duty on the part of all original investigators, and hardly less so of those who are the custodians of such invaluable evidence of the progress of natural science.

Local museums, as a rule, are less desirable repositories of type specimens than private collections, since the former usually can have little hope of permanent care, while the latter, if important, have a fair chance, by gift or purchase, of becoming part of a large endowed museum, where those in control are more likely to appreciate the importance of types, and carefully preserve them.

For the preservation of type specimens, fire-proof buildings are indispensable. I recall no less than five Museums of Natural History, in America, that have either been destroyed, or their contents consumed, or seriously damaged by fire, since I became actively interested in natural science. Several others, in the meantime, have had narrow escapes from the same danger, so that I regard all type specimens as insecure that are not preserved in buildings practically safe from fire.

Another danger to which type specimens are subject, is loss or injury during transit, when loaned or otherwise sent away from their regular place of deposit. This evil has become so serious, that some museum authorities do not permit type specimens to leave the building. This I regard as a wise regulation, and it is now in force at New Haven, and various other scientific centers.

If a type specimen is important, the investigator will come to the type. I once made a long pilgrimage to a famous university town, mainly to see a single bone, the "tibia" of an extinct reptile, according to the description, and the type of a new genus. I found the bone in good custody, and well preserved. It was not a tibia, however, but a radius, and this fact changed the classification based upon it. Had that bone been lost or destroyed, a new animal of strange proportions might have existed on the records of Paleontology, if not in Nature. That bone fortunately is still preserved, a witness whose testimony is conclusive.

When fossil skeletons are discovered in position, the best methods of preservation, especially of types, requires the retention as nearly as possible of the bones as found. One fore and one hind foot, at least, should always be kept in the rock, and all impressions in the matrix carefully preserved.

The importance of indelibly marking type specimens, and the separate parts of each, so that they may be studied essentially as found, is also evident. If a type is restored with plaster or other substance, the limits of each should not be so obscured that investigators cannot distinguish them. These are not imaginary precautions. Cases of the kind mentioned are not uncommon in vertebrate paleontology, as every worker knows. One well-known skull, with portions now preserved in two museums, is restored in one of them, as an original, and is thus misleading.

Type specimens preserved from other dangers may be injured unintentionally. Among the rare specimens damaged by zealous but unskillful hands in the house of their friends, three of the most important to paleontology, a reptile, a bird, and a mammal are well-known examples, and not a few others both in this country and America might be mentioned if it were proper to do so on this occasion. Such lack of intelligent custody of types will make the work of future investigators much more difficult.

An indirect way of preserving type specimens is by means of casts. These, if accurately made, may be of much service, and, in fact, an insurance on the original specimen. They may often save an investigator a long journey, and in case the type itself is lost or destroyed, the copy may prove of great value in indicating what the name was intended to cover.

Another indirect means of protecting type specimens would be to publish catalogues of them, giving the places where they are preserved. Such a list of a single group would be of great service to any one investigating it, and could be renewed from time to time whenever necessary. It would be well if everyone who described a species also stated where the type was deposited. In time this would become the established usage, and thus greatly facilitate the preparation of catalogues of types and their places of preservation.

Paleontology has been called an exact science, but its records up to the present time do not bear out this statement. If, as I believe, it will yet be worthy of such a distinction, one means of its advancement will be for those who represent it to select better type specimens, and preserve them more carefully.

In all branches of Natural Science, type specimens are the lights that mark the present boundaries of knowledge. They should be, therefore, not will-o'-the-wisps, leading unwary votaries of science astray, but fixed beacon lights to guide and encourage investigators in their search for new truth.

ART. XLI.—*The Origin of Mammals*;* by O. C. MARSH.

THE question under discussion is not new, but one of a series of similar nature and difficulty. The origin of Birds, of Reptiles, of Amphibians, and of Fishes really precede it, and offer less difficulties in solution. The answer to each, in my opinion, belongs to the future, and how far it may profitably be sought in the present limited state of our knowledge is a fair question in itself.

Too often in the past, a discussion on the origin of Mammals has seemed a little like the long philosophico-theologico controversies in the middle ages about the exact position of the soul in the human body. No conclusion was reached, because, for one reason, there were no facts in the case that could settle the question, while the methods of investigation were not adapted to insure a satisfactory answer. The present discussion is on a much higher plane, and the previous speakers have made an admirable presentation of their side of the case. I cannot, however, quite agree with them as to the value of the facts and theories they have presented, and shall consider the question from another point of view.

The Mammals, as we know them to-day, are classed by themselves, yet contain such diverse groups that it may fairly be regarded an open question whether all have a common origin. The attempt to ascertain whence they came is likely to bring out indications that they may have had several sources of origin, and this, if so, may help to explain the great diversity among them.

It is of course evident that some of the most characteristic features of recent mammals, for example, the hairy covering, the circulatory system, and the milk glands, cannot be used in a comparison with fossil forms. The osseous structure only is now available in the early mammals and other vertebrates, and in this alone points of resemblance must be found if different groups are connected genetically.

In considering the relations of reptiles to mammals so far as the fossil forms are concerned, which seems to be the main question before us to-day, I have only time to speak of the skull, and shall refer to some of its salient features already mentioned in this discussion; namely, the teeth, the squamosal bone, the quadrate, the occipital condyles, and with them the lower jaw. These perhaps may serve as crucial points in distinguishing the skull of a reptile from that of a mammal, even if they fail to indicate a near affinity between them.

* Remarks in the general discussion on the Origin of Mammals, at the International Congress of Zoology, Cambridge, England, August 25, 1898.

The different kinds of teeth seen in the reptiles regarded as mammalian in type, I consider of comparatively small importance, for the reason that the same general forms of teeth are to be found, not merely in the reptiles supposed to be nearest to mammals, but also in other groups widely different. In the Crocodiles, for example, the extinct genus *Notosuchus*, recently discovered in Patagonia, has all three kinds of teeth well distinguished. Again, some of the Dinosaurs, especially the genus *Triceratops*, have teeth with two roots, a supposed mammalian character. In some Fishes, also, (*Anarrhichas*) three kinds of teeth may be seen. It is more than probable, therefore, that the peculiar resemblance between the teeth of mammals and those of the lower vertebrates is merely one of parallel development, the adaptation being along similar lines, and in no sense an indication of genetic affinity.

The great development of the squamosal bone in Theriodont reptiles is not alone, for somewhat similar proportions are found in some other reptiles, for example, in the Plesiosaurs, where the squamosal is very large, and wrapped round the quadrate. In some of the Dinosaurs, also, (*Torosaurus*) the squamosal has an enormous development, while the quadrate remains of very moderate size.

The quadrate bone, always present in Birds, Reptiles, and the other lower vertebrates, is well-known as the suspensorium of the lower jaw, which meets it with a concave articular face. The quadrate, however, appears to be wanting in mammals, or at least has not yet been identified with certainty.

What represents the quadrate bone in mammals, is a vexed question in itself, and some of the best anatomists in the past, Cuvier, Owen, Peters, Huxley, and others, have endeavored to solve the problem. The tympanic bone, the incus, and the malleus have each in turn been regarded as the remnant of the quadrate, but up to the present time the question has not been settled. It is not improbable that the quadrate may have coalesced with the squamosal.

The occipital condyles of mammals, as well known, are two in number, and separated from each other. This is not the case with any true reptile, although the contrary has been asserted. The nearest approach appears to be where there is a single bifid condyle, cordate in shape, with the two lobes meeting below, as in some reptiles and a few birds, but not separate as in mammals and amphibians.

Finally, in all known mammals, recent and extinct, the lower jaw is composed of a single piece, and has a convex condyle meeting the skull by a distinct articulation. All reptiles, even those supposed to be nearest the mammals, have the lower jaw composed of several pieces, and these show distinct sutures between them, a profound difference that must be explained away before an approach can be made between the two classes.

It may fairly be said that the separate elements of the lower jaw, if present, would naturally be looked for in the Mesozoic mammals, and this point I have long had in mind. I may safely say that I have seen nearly every species of Mesozoic mammals hitherto described, and have searched for evidence on this point without success. I have also sought for the separate elements in the young of recent forms, but without finding any indications of them.

Beside the crucial points I have mentioned in the skull, there are others of equal importance in the skeleton, which I must not take time to discuss, but will venture to allude to one of them in passing. I refer to the ankle joint, which, when present, is at the end of the tibia in mammals, and in reptiles between the first and second series of tarsals. When we really find an approach between these two classes, the ankle joint will probably show evidence of it.

Having thus shown, as I believe, that we cannot with our present knowledge expect to find the origin of mammals among the known extinct reptiles, and that in attempting this we are probably off the true line of descent, it remains to indicate another direction in which the quest seems more promising.

Since 1876, when Huxley visited me at New Haven, and we discussed the probable origin of both Birds and Mammals, I have been greatly impressed by his suggestion that the mammals were derived from ancestors with two occipital condyles, and these were doubtless primitive Amphibians. I have since sought diligently for the ancestors of birds among the early reptiles, with, I trust, some measure of success, but this is a simple problem compared with the origin of mammals which we have before us to-day.

In various interviews with Francis Balfour, in 1881, at the York Meeting of the British Association, we discussed the same questions, and agreed that the solution could best be reached by the aid of Embryology and Paleontology combined. He offered to take up the young stages of recent forms, and I agreed to study the fossils for other evidence. His untimely death, which occurred soon after, prevented this promised investigation, and natural science still suffers from his loss. Had Balfour lived, he might have given us to-day the solution of the great question before us, and the present discussion been unnecessary.

The Birds like the mammals have developed certain characters higher than those of reptiles, and thus seem to approach each other. I doubt, however, if the two classes are connected genetically, unless in a very remote way.

Reptiles, although much lower in rank than birds, resemble mammals in various ways, but this may be only an adaptive likeness. Both of these classes may be made up of complex groups only distantly related. Having both developed along similar lines, they exhibit various points of resemblance that may easily be mistaken for indications of real affinity.

In the Amphibians, especially in the oldest forms, there are hints of a true relationship with both Reptiles and Mammals. It seems to me, therefore, that in some of the minute primitive forms, as old as the Devonian, if not still more ancient, we may yet find the key to the great mystery of the Origin of Mammals.

Art. XLII.—*Causes of Variation in the Composition of Igneous Rocks*; by T. L. Walker.

[By permission of the Director of the Geological Survey of India.]

Many attempts have been made to explain the causes of the variation observed in the composition of igneous rocks. This is particularly the case in "stocks" and dikes in which variation reaches its maximum. Frequently the border facies are more basic, though this does not always hold true. The Carrock Fell *massive* in the Lake district in England, the Meissen syenite *eruptive* in Saxony and some of the large nickel-bearing stocks in the Sudbury Nickel district in Canada are good examples of such differentiated *eruptives*. In all the above cases the border facies are basic—gabbro, norite, diorite, etc., while toward the center there is an increased acidity till syenite or granite is reached. The transition can generally be traced step by step, proving that the rocks so different chemically and mineralogically belong to the same eruptive and form a geological unit. A. C. Lawson has shown that in the dikes of the Rainy Lake district in Ontario the dike rock near the wall is fine-grained and quite basic—toward the center the rock becomes gradually coarser in texture and more acid in composition. Dikes do not show the very wide variation noted in stocks. This may be due to their much smaller dimensions and consequent more rapid solidification.

I propose to review briefly the more common theories advanced to explain the phenomena above referred to and to call attention to the part which gravitation seems to play in causing heterogeneity in eruptive rocks.

During the last few years many theories have been advanced to explain the differentiation of igneous rocks. It is probable that most of these theories are applicable in certain cases, but it is equally probable that no one theory gives a satisfactory explanation of all the phenomena observed. Better results may be attained by considering the manifold relations of fused magmas and tracing the influence of each of these relations on the homogeneity of the fused mass. The differentiated eruptive massive is the volume in which the history of these changes is more or less imperfectly recorded.

Fragments of country rock are often torn loose by the ascending molten magma and absorbed, thus causing the margin of the mass to be more acid or more basic than the more central portions of the stock or dike. This is a cause of variation, but cannot properly be spoken of as differentiation. It is not to be regarded as a chief cause of variation. If the difference in chemical and mineralogical composition were due to this

cause, we would expect to find the more acid facies of the eruptive in contact with the more acid country rock and the more basic facies in contact with the more basic country rock. These conditions are not always fulfilled—often quite the reverse. We are therefore justified in concluding that the absorption of inclusions of country rock plays only a very subordinate part in prodncing the variations observed in eruptive rocks.

Quite recently Johnston-Lavis* has drawn attention to the part played by osmotic force in the production of variations in igneous rocks. Suppose a laccolitic eruptive to be quite homogeneous at the time of its intrusion, then, according to this writer, there would be a gradual interchange between the magma and the country rock—material passing by osmotic force from the magma to the country rock and *vice versa.* If the magma were acid and the country rock basic the former would become basic toward the contact and the country rock would become more acid. The laccolite would be basic on the borders and would become gradually more acid toward the center, where it would possess the composition of the original magma. True, this would seem to account for the variation within the eruptive, but what must we conclude with regard to the heterogeneity caused in the country rock? We would expect the metamorphosed country rock to resemble (chemically) the eruptive near the contact, while the less metamorphosed rocks would be less changed chemically. This, however, is at variance with the conclusions based on analyses of series of rocks from contact areas. Several series of analyses of contact products agree in demonstrating that no important chemical change accompanies such contact metamorphism.

Homogeneous salt solutions become heterogeneous if slight difference of temperature be maintained in different parts of the solution. A solution placed in a long horizontal tube will become slightly concentrated in the cooler end of the tube. This principle of Soret's was first used to explain differentiation in rock magmas by Teall.† Supposing the magma to be an homogeneous mass at the time of intrusion and regarding it as a solution, we would expect that the "dissolved" would concentrate in the cooler parts adjacent to the country rock. Since the basic borders are characterized by the bases CaO, MgO and FeO, they or their silicates are regarded as the "dissolved." More recently Harker‡ has criticised this theory of differentiation and concludes that it can account for only slight

* Causes of variation in the composition of igneous rocks, Natural Science, 1894.

† British Petrography, 1888, p. 404.

‡ On the Gabbro of Carrock Fell, Quart. Journal Geol. Soc., 1894.

variations. According to Soret's principle, the concentration is proportional to the absolute temperature. Thus, in order to have twice as much of these dissolved bases or their silicates at the border as at the center of the eruptive, we would require to suppose that at the time of solidification the absolute temperature at the center was twice that at the border. Suppose the temperature at the border of the magma were 700° C. or 973° absolute temperature, then the absolute temperature at the center would have been 1673° C. or 1946°. Are such differences in temperature to be expected? Scarcely. Besides Soret's principle has been established for only very *dilute* solutions and for only slight variations in temperature. The separation of masses of nearly pure ilmenite as border facies on basic eruptives would, as pointed out by Harker, require much greater difference of temperature, as the proportion of iron in these masses is often twenty-five times that contained in the central part of the eruptive. Such great differences in temperature would give rise to convection currents in the magma which would render differentiation quite impossible.

It should not be forgotten, however, that in all probability differentiation and solidification were in progress at the same time, so that we should compare the proportion of the "dissolved" contained in the very narrow strip along the border, not with the proportion contained in the present center, but with that contained in the magma which occupied the center at the time when the first border strip solidified, since the present central rock is more acid than the magma which occupied the center during the earliest stages of differentiation. Similarly the next narrow strip should be compared with the magma which occupied the central portions of the eruptive reservoir at the time when the narrow strip in question solidified. In this way the argument of Harker is weakened though not destroyed.

Vogt* accepts Soret's principle as having been a prominent cause of differentiation and even of the formation of marginal deposits of sulphide ores such as the Canadian and Norwegian nickel deposits, and of deposits of titanic iron ores such as those of Baie St. Paul on the Lower St. Lawrence. He is of the opinion, however, that magnetic forces may have had an influence in localizing minerals rich in iron, after their crystallization from the magma. In this connection it is interesting to notice that minerals rich in iron are generally among the first to crystallize and that in differentiated eruptive areas they are almost invariably concentrated as border facies.

Harker† maintains that the tendency to homogeneity in

* Stockh. geol. Fören. Förh., xiii, 1891, pp. 520–683.
† Loc. cit.

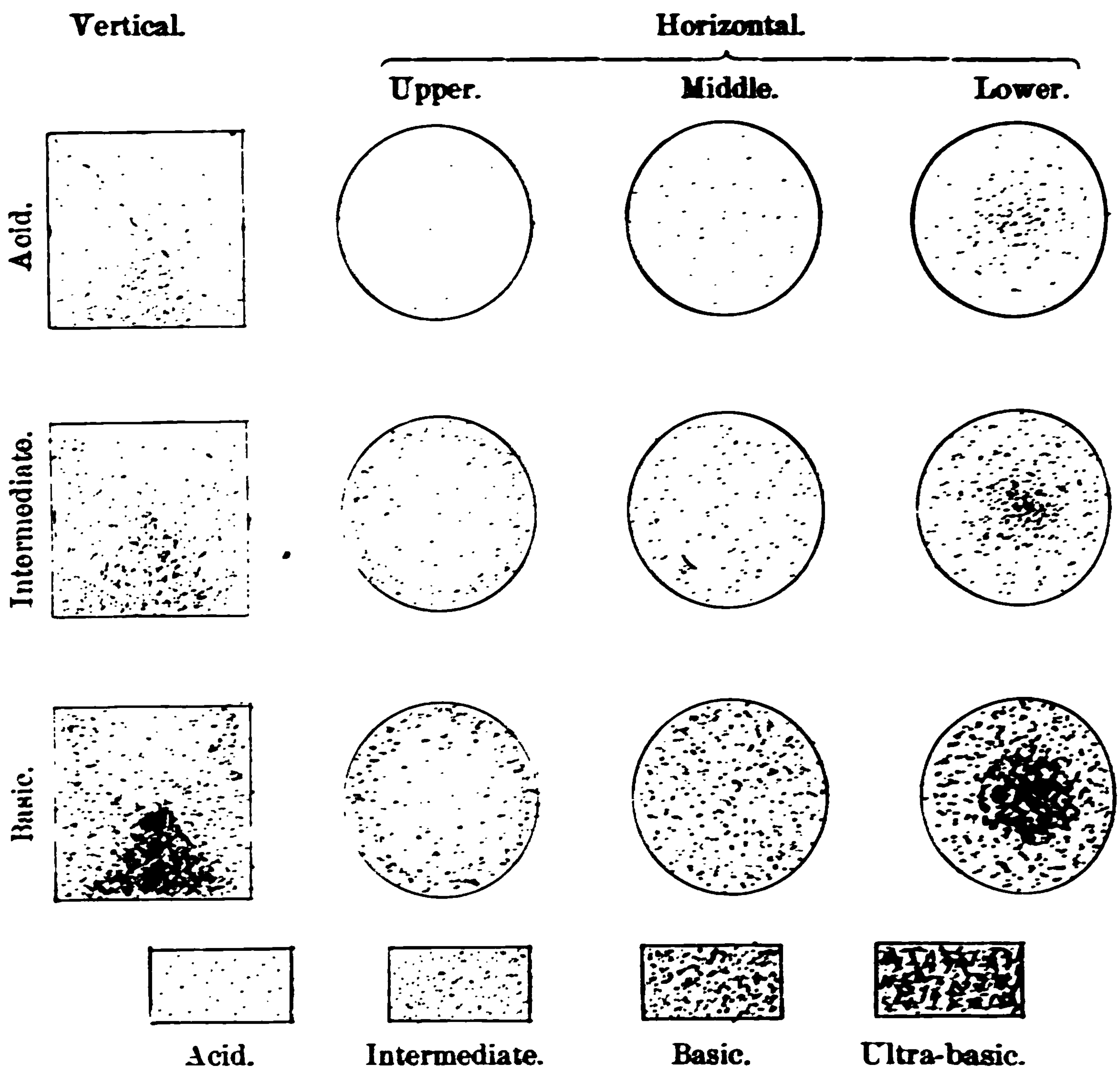
solutions plays a more prominent part in the production of variation in igneous rocks than the tendency to heterogeneity as emphasized in the case of Soret's principle. Suppose a magma of homogeneous composition to become cooled along the border so that some of the constituents begin to crystallize out on the wall rock. The first to separate would be the minerals characteristic of basic borders. The deposition of these minerals from the magma would introduce heterogeneity into the magma. Diffusion would tend to restore homogeneity, thus causing a movement toward the border of the substance necessary for the continued formation of the minerals which had separated. The result is the same as that attained by Soret's principle, but the causes are quite different—the one is the tendency to homogeneity, the other to heterogeneity. Harker's view is based chiefly on the fact that the basic borders are composed of the minerals which are among the first to crystallize from molten magmas. Such early crystallizing minerals are—olivine, various pyroxenes, biotite, basic plagioclases, iron oxides and sulphides. On the other hand acid plagioclase, orthoclase, quartz and muscovite, which characterize more acid rocks, are generally absent from the basic borders. The basic minerals crystallize along the border just as a crystal grows when suspended in a saturated salt solution—by appropriating the salt within its "court" (Hof), which in turn is constantly being replenished by diffusion (the tendency to uniformity) from the more distant parts of the solution.

Some homogeneous salt solutions, if allowed to remain at constant temperature for a long time, become gradually more concentrated in the lower strata.* It is very probable that similar concentration occurs in complex silicate magmas, particularly near the temperature of solidification. An eruptive magma would therefore tend to become acid above and basic below. Since the margin becomes cooled comparatively quickly, the rock which solidifies along the border will have had very little time to become differentiated and will consequently possess nearly the same composition as the original homogeneous magma. Differentiation and solidification progress simultaneously, and hence the rocks farthest from the border will have suffered the greatest differentiation and will vary most in chemical composition. In the upper horizons of the eruptive there would be a gradual increase of acidity toward the center; the middle horizons would show very little differentiation while sections through the lower portions of the reservoir would show an increased basicity toward the center. All of these cases are well known in field explorations.

* Gouy and Chapéron, Ann. chim. phys., 1887, p. 387.

It is improbable that this is ever the only cause tending to produce variations in the composition of dikes and stocks.

Frequently eruptive stocks possess basic borders and acid centers, but on the other hand there are a few well known eruptives where the central portion is much more basic than the margin. Vogt* says that in many Norwegian occurrences, the central portions are very basic, even to the extent of large masses of titaniferous iron ore. Though there are only a few such cases, yet they must be taken into account. Such occurrences are anomalies according to all the old theories of differentiation outlined above, but they are quite regular when considered in connection with the explanation offered in the



previous paragraph. In fact we should expect to find such cases. In order to obtain a section of a stock showing a basic border and an acid center, it is necessary that the original magma should have been basic, and to have a section from an upper horizon of the reservoir. If, however, the original magma were of an intermediate composition, say 60 per cent

* Zur Classification der Erzvorkommen, Zeitschr. f. prakt. Geologie, 1894.

SiO_2, and we have a section from near the base of the reservoir, we would expect the border to possess the same composition as the original magma and the center to be basic. Similarly all sections from the middle horizons of reservoirs should show little or no differentiation. This is illustrated by the accompanying diagrams. Suppose the reservoir, for the sake of easy representation, to be cylindrical. The four upper figures represent sections through a differentiated massive resulting from a magma whose original composition was acid—the first figure representing a vertical section; the other three horizontal figures form upper middle and lower horizons. Similarly the four figures in the second row represent sections of a massive whose original magma was of intermediate composition. The third row represents sections derived from a stock whose original composition was basic.

A priori we should expect that the greater number of exposed sections of eruptive stocks would be from the middle horizons, that a much smaller number would represent the uppermost horizons and that a very small number would represent the lowest horizons. This agrees exactly with the facts as revealed by geological field work, viz., most stocks as exposed show little or no differentiation, a much smaller number have basic borders and acid centers, while a very small number show acid borders and basic centers.

The weakness of this theory consists in its fundamental principle—that gravitation causes a concentration in some solutions. Some physicists deny this, but the men who have investigated it most are quite confident that differentiation does take place.

Indian Museum, Calcutta, Nov. 10th, 1897.

ART. XLIII.—*The Relation between Structural and Magneto-optic Rotation;* by A. W. WRIGHT and D. A. KREIDER.

THE fact that any transparent, simply refracting, optically inactive substance when placed in a powerful magnetic field instantly acquires the property of rotating the plane of polarized light, and that the effect thereon is apparently of the same nature as that characteristic of certain specific atomic groupings in molecules, as, for example, those containing the asymmetric carbon atom, or of a particular molecular aggregation in certain crystalline units, such as sodium chlorate, naturally raises the question of relation between the two causes. Upon this subject literature furnishes no decisive records. Verdet's admirable researches have brought to light many interesting facts in regard to the two rotations, but none upon the subject here proposed.

It is known that when an optically active substance is placed in a magnetic field the two rotations are superposed, so that the resultant optical activity is the algebraic sum of the structural and magnetic rotations. An interesting result is Verdet's observation upon the behavior of iron and some other magnetic substances, to the effect that these, contrary to the general rule, rotate the plane in a direction opposite to that of the electric current or magnetic whirl.

It seemed worth submitting to an experimental investigation whether, if the optically active molecular structure or aggregation were effected in a magnetic field, it would be influenced thereby to an extent sufficient to show in its final optical properties, which would seem probable providing the interatomic or intramolecular forces are electrodynamic.

Experiments on Tartaric Acid.

Tartaric acid, three of the four isomeric forms of which are optically different, seemed applicable in this investigation, and upon it the first experiments were made.

Ordinary dextrotartaric acid, when heated to 175° C. in the presence of water in sealed tubes, is gradually converted into equal amounts of the racemic and the inactive forms.* If the atomic arrangement in this molecule is subject to the influence of magnetic force, it might be expected that by effecting the above change in a magnetic field, the resulting product should differ from that ordinarily obtained. For instance, if the molecules or their factors possess polarity, the magnetic field should exert upon them a directive action, and it

* Jungfleisch, Jahresb., 1872, 515.

might be expected that the resultant polarization would be influential in determining the final form assumed.

In the following experiments two coils, made of german-silver wire carefully insulated by asbestos wrapping, furnished at once the required temperature and magnetic field. The coils were 160^{mm} long, with an opening into which a tube of 16^{mm} diameter would snugly fit. They were composed of four layers of wire each containing forty turns, one end of each layer being brought out so as to permit of connection in series or in opposition, thereby making it possible to eliminate the magnetic effect without altering the temperature. With the current strength employed, which was from two to three amperes, each coil, with layers connected in series, gave a calculated magnetic field of between forty and fifty C. G. S. units.

The determinations were all made in pairs: one in a magnetic, the other in a neutral coil; and the period of heating varied from two to four days for each experiment, this being the limit set by the unavoidable carbonization which, if carried too far, detracts from the delicacy of the polariscope reading; while the incidental evolution of carbonic acid results in such an increase of pressure that, though the tube should withstand it, partial loss of contents by violent effervescence upon opening the tubes is inevitable.*

As a rule the tubes contained 5 grms. of dextrotartaric acid with 3^{cm^3} of water and, in order to reduce the pressure by expelling the air, were sealed while the contents boiled. At the conclusion of the experiment the tubes were emptied into 50^{cm^3} flasks, from which the portions tested were filtered into the polariscope tube.

Preliminary tests seemed to indicate a slight influence pointing toward a tendency of the molecules under these conditions to group in the same way, that is to produce one product more abundantly than the other.

In order to determine certainly whether or not this effect was invariable, a series of some twenty determinations was made under carefully regulated conditions. The quantities of tartaric acid were accurately weighed and the water measured with equal care. To avoid any possible effect due to difference of pressure each pair of tubes was exhausted by a water pump and sealed off at the same instant and at the same length. The temperature of the two coils was accurately equalized, each being then protected from loss by radiation by means of loose coverings of asbestos and finally enclosed in the same

* It may be worth observing that the glass tubes thus employed have so yielded to the pressure at the temperature of these experiments as to make their further use impossible, unless perchance reannealing should restore their strength. The glass, however, did not appear to be chemically acted upon as it is by pure water when heated to that temperature.

wooden box, which was made long enough to permit of their being placed at sufficient distance from each other to avoid any appreciable interference in their magnetic fields. To counteract any possible slight difference in the effect of the two coils, the tubes, after half of the time of heating, were changed from one coil to the other and the magnetic conditions with them. Finally, to avoid any variation in the action due to a difference of density in the two tubes, since the amount of water employed was insufficient for a complete solution of the acid at the ordinary temperature, the tubes were agitated at certain intervals to insure uniform and equal density in each.

With these precautions to have the conditions of each tube identical save in the magnetism, the series of determinations referred to failed to indicate any influence of the magnetic field, the rotation having been diminished by the same amount in each case.

Experiments upon Racemic acid.

Experiments were also made, under the same conditions, upon racemic acid; it being thought that this, being an equimolecular union of both forms, would be more likely to show an effect when placed in a magnetic field more favorable to the existence of one form than the other. Finally a small percentage of the dextro acid was added in the hope that a little excess of dextro would help the turning, but in neither case was any effect noted.

Experiments on Sodium Chlorate.

Identical considerations led to a like investigation of the crystallization of sodium chlorate in a magnetic field.

Landolt and others have found that ordinarily sodium chlorate will, if undisturbed during spontaneous evaporation, deposit equal quantities of dextro- and laevo-rotatory crystals. The experiments here recorded also confirm this observation in general. Presumably Landolt has not meant that the quantities of dextro and laevo crystals are exactly equal, but that they are practically so, and the number of determinations recorded in this paper, which are only a small part of the number actually made, will show that while there is a tendency to form in equal amounts, there is almost invariably a slight excess of one or the other which often may be considerable, yet to all appearance wholly accidental.

That there is nothing inherent in the individual molecules of this substance which possesses rotary power or which determines the optical activity of the crystalline aggregate, is

pretty well established. Its solution possesses no activity,* and Landolt† has further proved that even the supersaturated solution fails to exhibit the slightest optical activity. Moreover, the form which the crystals assume can be influenced and determined by external causes. Thus it has been pointed out by Gernez‡ and by Landolt,§ in a slightly different way, that if into a supersaturated solution of sodium chlorate some fragments of dextro or laevo crystals are placed, only crystals of a like nature result. These experiments we have repeated but not with the extreme results noted above. While invariably there is a very marked preponderance of the same kind of crystals as those introduced, we have never failed of finding a very considerable quantity of the opposite kind. In order to put on record something more definite in regard to the relative quantities of the two forms deposited under these circumstances, we give in Table I the results of three experiments chosen at random from a considerable number. The rotation was determined by suspending 0·2 grm. of the finely powdered product in a liquid of the same refractive index, according to the method given at the end of this paper.

TABLE I.

Crystals deposited from a saturated solution of $NaClO_3$, to which had been added:

	Resultant rotation in divisions of scale.	
1. A sprinkling of powdered *dextro* crystals	+4·36 (i. e., 74%)	Large crop; all small crystals, but distinctly crystalline.
2. A sprinkling of powdered *laevo* crystals	−4·2 (i. e., 73%)	Large crop; all small crystals, but distinctly crystalline.
3. One large and five small *dextro* crystals	+ 1·86	The six original crystals, which had doubled in size, were removed before testing the rotation.

Rotation of an equal wt. of pure dextro or laevo forms, ± 8·96 division.

It has even been claimed‖ that the influence of a small percentage of some other optically active body in solution with the sodium chlorate influences the formation of the crystals, a conclusion which, however, our results as recorded in Table IV, with comment, do not sustain.

* Marbach, Pogg. Ann., xci, 487.
† Ber., xxix, 2. 2410.
‡ Compt. Rend., lxvi, 855.
§ Loc. cit.
‖ Pope and Kipping, Chem. News, lxxv, 45.

One convincing proof of the optical indifference of the ultimate molecule of sodium chlorate is found in the fact observed in one of our experiments, that from a filtered solution of pure dextro-rotatory crystals, upon spontaneous evaporation, a very decided *excess* of laevo crystals was obtained.

In the light of these facts as to the optically indifferent nature of the molecule of sodium chlorate and the ease with which its optically active molecular aggregation in the crystalline unit is influenced, it certainly is not unreasonable to suppose that, since this particular molecular aggregation results in the rotation of the plane of polarization in a certain direction, if by means of the magnetic field we introduce forces tending to produce rotation, it should result in a directive action upon the molecules in this field, thus producing a preponderance of those crystals whose optical activity corresponds to the field in which they were formed.

In the theoretical consideration of the possible influence of magnetism upon the formation of optically active structure, it should be recalled that a very characteristic difference exists between natural and magneto-optic rotation, namely, that if a ray of polarized light is caused to retrace its path through an optically active natural substance, the plane is rotated in the opposite direction so that the resultant rotation is zero, while in the magneto-optic phenomenon the rotation is independent of the direction in which the ray travels, the rotation being increased as many times as the ray has passed through the medium. Moreover, structural rotation is active and specifically equal in every direction, while the magnetic rotation varies from a maximum in the direction of the lines of magnetic force, to zero at right angles thereto; in other words, varies as the cosine of the angle which the ray makes with the lines of force. However, the magnetic whirl by itself appears to be incapable of rotating the plane of polarization, at least to any perceptible extent. The molecules of the medium placed in the magnetic field seem to be essential to the phenomenon, from which fact it is evident that the action in the ether which takes place about the lines of magnetic force, causes a change in the orbit or nature of the vibration of the molecule, which consideration would still leave probable, during the period of formation at least, some influence of the magnetic field upon the molecular aggregation in the crystalline unit of a substance such as sodium chlorate, in which there is nothing inherent in the molecule which determines the optical nature of its aggregation.

Nor can this fact, that the natural and magneto-optic rotations are superposable without permanently affecting the structure, be considered conclusive against the supposition, the

experimental investigation of which forms the subject of this paper; unless indeed it should be possible by superposition of the magneto-optic rotation to *completely reverse* the structural rotation, i. e., so that the resultant rotation should be of opposite sense to the original structural rotation, under which circumstances it might be possible that the molecules would rearrange themselves by swinging over into the enantiomorphic forms possessing that rotation, just as by external force the molecules in a crystal of calcite may be made to slide or swing from one position of equilibrium to another, or from one form to its twin, under the influence of pressure; the phenomenon being unaccompanied by any serious disturbance such as the disintegration of the crystal.

However, since the magneto-optic rotation is small, even in the most powerful electro-magnetic fields, the facts observed would appear to be accounted for, and the reversal of the structure would not be expected though an influence might be looked for during the period of formation of the body.

To determine the truth or error of this supposition, as to the possible control of the final product, by securing conditions favorable to one and antagonistic to the other of the enantiomorphic forms, a large number of crops of sodium chlorate crystals were allowed to grow by spontaneous evaporation in magnetic fields with the results recorded in the following tables.*

TABLE II.

Crystals grown *over* N-pole of a vertical bar magnet.

		Crystals.		Excess by		Dextro	Remarks.
		No.	Wt.	No.	Wt.	% by wt.	
1.	Dextro..	5	....	..	one crystal	about	
	Laevo ..	9	....	4	not weighed	60	All large crystals.
2.	Dextro..	..	1·232	..	0·675	68·8	Dextro crystals larger than the laevo.
	Laevo ..	..	0·557	..			
3.	Dextro..	77	0·857	35	0·317	60·9	
	Laevo ..	42	0·540	..	....		
4.	Dextro..	31	0·418	..	0·083	55·5	
	Laevo ..	31	0·335	..	....		

Table II shows the results of four crops obtained over the north pole of a bar magnet. Here the excess of dextro crystals in each case is conspicuous, and taken by themselves these results are misleading. Viewed in the light of the succeeding tables it appears probable that the uniformity here noted is purely accidental.

* A thin ring of vaseline along the sides of the vessel was found very effectual in preventing the creeping of the solution during crystallization.

TABLE III.

(*a*) Crystals grown *over* S-pole of the vertical bar magnet.

	Crystals. No.	Crystals. Wt.	Excess by No.	Excess by Wt.	% of Dextro by wt.	Remarks.
1. Dextro..	..	1·258	..	....		Laevo rather larger.
1. Laevo ..	..	1·709	..	0·451	42·4	Uncertain, 0·333 grm. ∴ Excess if *all* this counts as laevo = 0·117 grm.
2. Dextro..	30	2·040	..	1·320		
2. Laevo ..	64	0·720	34	....	73·9	All good size. Dextro rather larger.
3. Dextro..	75	0·510	..	....		
3. Laevo ..	77	0·677	2	0·167	43·0	
4. Dextro..	58	0·350	10	0·107		
4. Laevo ..	48	0·243	..	....	59·0	
5. Dextro..	23	1·610	2	0·129		5 of laevo crystals large, remainder very small.
5. Laevo ..	21	1·481	..	....	52·1	
6. Resultant rotation				= − 0·5	47·2	Crystals distinct but small. Determined by method given at end of this paper.
7. " "				− 0·1	49·4	
8. " "				− 0·03	49·8	
9. " "				− 1·96	39·1	
(*b*) Crystals grown *under* the N-pole.						
10. Dextro..	34	0·450	..	....		All clear and beautifully crystallized.
10. Laevo ..	42	0·525	8	0·075	46·1	
11. Dextro..	18	0·880	..	....		Irregular in size. Uncertain 0·045 grm.
11. Laevo ..	33	1·633	15	0·753	35·0	
12. Resultant rotation				= − 3·5	30·5	Crystals distinct but small. Determined by method given at end of the paper.
13. " "				− 1·9	39·4	
14. " "				− 2·8	34·4	
15. " "				− 0·04	49·8	

Here again, especially in (*b*), a curious preponderance, this time of laevo crystals, is noted: but providing the effect to be sought for is that due to the *direction* of the magnetic whirl the results in (*a*) and (*b*) are inconsistent, since in both cases the direction of the lines of force and hence of the magnetic whirl is the same. However, from what has been said in regard to the difference of the structural and magnetic rotations, it is evident that the sense of the resultant activity could not be predicted.

In order to test the effect of a more powerful magnetic field a Jamin magnet was supported vertically, so that a thin glass, flat-bottomed beaker having a diameter marked upon it, could be symmetrically placed over the poles and the crystals formed on each side of the dividing line be separately tested. But the result of a large number of crops so far as the optical activity is concerned was disappointing. While an increased effect might have been expected or at least a verification of the experiments with the bar magnet, the results are

practically identical with those obtained without the use of any magnet.

However, there seemed to be a tendency to group over the poles. Though nothing very definite could be said about the observed arrangement of these clusters, it may be positively asserted that the distribution of the crystals under these circumstances was different from that ordinarily obtained, that is without the use of a magnet.

In order to get a still more intense field the Jamin magnet was supported horizontally with its poles in a vertical line and the crystallization was effected in a small vessel made of tin-foil of just the proper size to fit between the poles, so as to be in the strongest part of the field. Measurements proved the field at this point to be about 800 C. G. S. units. Some difficulty was experienced in getting the crystals to grow in this vessel, but by cutting a plate of thin glass to fit the bottom this difficulty was overcome, doubtless because the glass afforded more nuclei about which the crystals form. A number of crops thus collected failed to reveal any effect of this magnetic field upon the optical property of the crystals.

Crystallization of Sodium Chlorate in Electrostatic Field.

Incidentally the effect of an electrostatic field was also investigated. For this purpose a Leyden jar was charged from an electric machine. The poles from the two surfaces, after being capped by fairly thick glass tubes in order to prevent discharge, were brought as close together as was permitted by the solution contained in a shallow, thin-glass, flat-bottom beaker placed between them. Several preliminary experiments were made, but no particular effect was noted upon the formation or arrangement of the crystals in this field, nor upon the resultant optical activity of the crop of crystals.

Experiments on Ferrous Sulphate.

The tendency of the crystals of sodium chlorate to group over the poles of the magnet, led also to some experiments upon the crystallization of an iron salt in a magnetic field. It was thought that because of its magnetic property the iron would show a more decided effect. A number of experiments fully confirmed this expectation. In each case the grouping over the poles was very conspicuous and unmistakable. There was, however, nothing definite in the arrangement of these crystals or of their axes beyond the marked tendency to form in the strongest part of the magnetic field.

Method of determining the resultant optical activity of a crop of crystals.

There is one point in the determination of the *resultant* optical activity of crops of crystals which does not appear to have been fully appreciated heretofore, which we would specially emphasize. It has been observed* that not all crystals which show a dextro or laevo rotation are necessarily pure forms. At times the twinning is almost if not entirely imperceptible, so that a crystal which may appear homogeneous and as a whole rotates the plane of polarization to the right or to the left, is found not to have the proper specific rotation, showing that in fact it is a combination of both forms with a preponderance of one or the other. It is evident, therefore, that in the determination of the excess of one or the other of the enantiomorphic forms in a crop of crystals, whether the basis of comparison be the number of crystals or their weight, an error might result.

Among the many crops of crystals prepared during this investigation, a number of crystals of this kind appeared, some of which were more or less conspicuous for irregularities in structure and yet to all appearances were decidedly more like a single crystal than an aggregate, but the magnitude of their rotation was not commensurate with their thickness.

Moreover, very often the crystals are small and intergrown to such an extent as to make an accurate investigation of their rotation very tedious and difficult, if not impossible.

It is evident then, from both of these considerations, that greater accuracy and economy of time would result from a direct determination of the resultant rotation of the whole crop. This may be accomplished by the elegant method developed by Landolt,† founded upon Christiansen's experiments,‡ according to which the finely powdered crystals are suspended in a liquid of the same refractive index which has no solvent effect upon them. This method, with some slight modifications which we found desirable, was as follows.

The crystals were finely powdered in an agate mortar, and in order to secure greater uniformity in size and thoroughness of mixture, passed through a very fine sieve. Having the crystals hot at the start greatly facilitates the attrition as well as the sifting. A mixture of absolute alcohol and carbon disulphide in the proportion of one part of the former to two of the latter furnishes a liquid of the same refractive index in which the crystals are entirely insoluble. Commercial "abso-

* Marbach, Pogg. Ann., xci, 486; Landolt, Ber., xxix, 2, 2412.
† Ber., xxix, 2, 2404.
‡ Wied. Ann., xxiii, 298.

lute" alcohol will answer the purpose so far as the transparency of the mixture is concerned, and any slight solvent effect can be eliminated by preparing the mixture in a test tube containing some powdered sodium chlorate, which is further required as an indicator since the carbon bisulphide must be added finally drop by drop till the maximum transparency is secured, then filtering into the polarimeter tube containing the powder to be tested.

The greater specific gravity of the sodium chlorate necessitates continual rotation of the polarimeter tube in order to keep the powder in suspension. This was effected in a very simple way by slipping corks of proper size for the polarimeter over both ends of the tube and turning a slight groove in each, in which ran an endless string from two wheels on an axis directly above. By wrapping the tube with a small piece of sheet lead, sufficient weight was given it to cause a regular and smooth rotation when the wheels from which it hung were rotated by a small electric motor worked with one Grove cell. This simple device makes it possible, with a very little rigging, to rotate a tube in any polarimeter which may be at hand.

Landolt has pointed out that the rotation should be maintained at between 50 and 80 revolutions per minute, in order to have uniform suspension without the centrifugal action.

In all of the experiments in which we employed this method, 0·200 grm. of the sodium chlorate was taken after the whole crop of crystals had been reduced to a uniform powder and thoroughly mixed.

Effect of the presence of optically active substances in the solvent medium.

During the course of this investigation the peculiar results obtained made it seem worth while to repeat the experiments of Pope and Kipping* previously referred to, since the suspicion had arisen that their conclusions may have been based upon insufficient data, just as it might have been inferred from the results recorded in Table II of this paper, had not further experiment failed to verify it, that the magnetic field determined the form of the crystals.

Accordingly a five per cent solution of dextrose was prepared as they have stated and subsequently saturated with sodium chlorate. Three portions of this solution were filtered and allowed at the same time to crystallize by spontaneous evaporation in a place free from vibrations or any apparent cause of disturbance. Curiously each of the three crops was found to have an excess of dextro crystals. Pope and Kipping

* Chem. News, lxxv, 45.

have announced that under these circumstances an invariable excess of laevo crystals should form. Three more crops were grown under the same conditions and curiously again these three all had an excess of laevo crystals. Other crops were then grown and the percentage of dextrose in solution increased, but it was found to have no effect, the crystals coming down one time with an excess of dextro and the next time with an excess of laevo, as is shown by Table IV, results which in no way differ from those obtained where the crystals are formed in the ordinary way.

TABLE IV.

		Crystals by No.	Crystals by Wt.	Excess by No.	Excess by Wt.	% of Dextro.	Remarks.
1.	Resultant rotation				= + 2·84	65·8	First set. Good crop of sharp and clear but small crystals.
2.	" "				+ 2·46	63·7	
3.	" "				+ 0·94	55·2	
4.	" "				− 0·37	47·9	From mother liquor of 1–3. Good clear crystals.
5.	" "				− 0·7	46·1	
6.	" "				− 1·24	43·1	
7.	Dextro	9 ?	0·670	--	----		Clusters and fragments made number uncertain.
	Laevo	16 ?	0·825	7 ?	0·255	44·8	
8.	Dextro	3	1·060	--	0·455		4 large crystals, of which 3 were dextro and 1 laevo; remainder small and all laevo.
	Laevo	13 ?	0·505	10	----	67·7	
9.	Resultant rotation				= − 0·55	46·9	From mother liquor of 7–8.
10.	Dextro	32	1·640	18	0·875		Mother liquor of No. 9 with addition of some of original solution. Large, fine crystals.
	Laevo	14	0·765	--	----	68·2	
11.	Dextro	104	1·172	15	0·147		
	Laevo	89	1·025	--	----	53·3	Uncertain, 0·031 gm.

Pope and Kipping do not state the number of results upon which they have based their conclusions, but our experience indicates that, whatever be the undetermined cause* of this varying excess of dextro or laevo crystals, whenever several crops are allowed to grow under the same circumstances, each being portions of the same solutions, taken at the same time, the causes acting on each are likely to be the same, and to give rise to an excess of the same kind of crystals in each case. Therefore to determine whether or not any special influence is exerted by extraneous forces a sufficient variety should be given to the experimental conditions to assure the unmistakable revelation of this influence.

* Is it the influence of the first crystal formed?

TABLE V.

Sodium chlorate from saturated solution by spontaneous evaporation.

		Crystals by		Excess by			
		No.	Wt.	No.	Wt.	% of Dextro.	Remarks.
1.	Dextro..	41	0·870	7	0·37		
	Laevo ..	34	0·500	..	..	63·5	
2.	Dextro..	18	0·546	..	..		
	Laevo ..	24	0·630	6	0·084	46·4	All clear and large.
3.	Dextro..	30	1·306	..	0·130		Uncertain = 0·130 grm.
	Laevo ..	30	1·176	..	..	52·6	
4.	Dextro..	4	0·285	..	0·183		
	Laevo ..	7	0·102	3	..	73·6	
5.	Dextro..	10	0·612	..	..		Uncertain 0·025 grm.
	Laevo ..	18	1·127	8	0·515	35·2	
6.	Resultant rotation			=	−4·0	27·7	After evaporating to dryness (spontaneous).
7.	" "				+0·6	53·3	
8.	" "				−0·6	46·7	
9.	" "				−1·4	42·2	

Conclusion.

The results obtained from these experiments show no marked and indisputable evidence of the influence of the magnetic field upon optically active structure. However, a review of the results seems to indicate a disturbance of the equilibrium by the magnetic field which results in a rather greater variation from the neutral crop of sodium chlorate crystals than is ordinarily obtained, but without revealing any definite influence in regard to the *direction* of the resultant rotation.

It might appear that a force however feeble should be sufficient to exert a directive action upon the substance during the period of formation, which, if true, gives the results previously discussed the greater weight, since even the strongest magnetic fields employed have failed to control the *direction* of the resultant activity.

Sloane Physical Laboratory, Yale University,
June 1, 1898.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On Crystallized Metallic Calcium.*—The preparation of practically pure metallic calcium in the crystalline form, has been described by Moissan. For this purpose he has made use of the fact that metallic calcium is soluble in liquid sodium at the temperature of dull redness. On cooling, the calcium crystallizes out and on removing the sodium by means of absolute alcohol, white, brilliant hexagonal crystals of pure calcium are obtained. In an iron crucible, holding about a liter, are placed 600 grams of crystallized anhydrous calcium iodide and 240 grams of sodium; three times the sodium required by the equation $CaI_2 + Na_2 = Ca + (NaI)_2$. The crucible is closed with a screw top and is then placed in a furnace and maintained at a dull red heat for about an hour, being occasionally shaken. On opening the crucible after cooling, it contains a blue mass of the melted salt upon which rests a cake of metallic sodium. This cake is broken into fragments and thrown into a liter flask containing 500^{cc} of absolute alcohol cooled by ice. When the evolution of hydrogen has ceased, the liquid is decanted and an equal quantity of absolute alcohol is added. This washing is continued until the alcohol shows no residue on evaporation. The brilliant powder left behind is treated with absolute ether and then dried in a stream of dry carbon dioxide or hydrogen. It is preserved in a sealed tube. The yield is about 50 per cent of the theoretical quantity, about 40 grams being obtained in each operation. Crystallized metallic calcium may also be obtained by electrolyzing fused calcium iodide at a red heat, the negative electrode being pure nickel and the positive a graphite cylinder placed in a porous cup. On analysis the metal thus obtained gave 98·9, 99·1 and 99·3 per cent of calcium in three samples.—*C. R.*, cxxvi, 1753–7, June, 1898. G. F. B.

2. *On the Preparation and Properties of Calcium Hydride.*—The direct union of calcium and hydrogen to form a hydride has been effected by Moissan. The pure crystallized calcium above described is placed in a nickel boat in a glass tube through which passes a current of pure and dry hydrogen, prepared by passing it successively through two red hot porcelain tubes, containing copper turnings and pure boron respectively. The gas is then dried by fused potash and phosphoric oxide calcined in a current of oxygen. After the tube has been filled with hydrogen, the end is sealed and the gas pressure is increased to 30 or 40^{cm} of water. The temperature is then slowly raised and when it attains a red heat the calcium takes fire; the gas is rapidly absorbed and a white fused mass of calcium hydride is obtained. It has a crystalline fracture, a density of 1·7, and is not dissociated at 600° in a vacuum nor at the temperature of melting Bohemian

glass in air. Even at a red heat, it is unchanged in air; though it takes fire in the blowpipe flame. Thrown into water, the latter is decomposed and its hydrogen unites with that of the hydride, producing calcium hydrate and hydrogen. Its composition is CaH_2 and it acts energetically as a reducing agent.—*C. R.*, cxxvii, 29, July, 1898. G. F. B.

3. *On an Improved method for determining Molecular Mass by the Boiling Point.*—Early in the present year, Landsberger described* an improved apparatus for fixing the molecular mass of a substance by means of the elevation which it produces in the boiling point of a solvent when dissolved in it. In this apparatus the solution is kept at its boiling point by the passage through it of the solvent vapor alone, thus avoiding superheating. WALKER and LUMSDEN have now proposed a modification of this method which consists in measuring the *volume* of the solution after equilibrium has been attained, instead of its *weight*. The apparatus consists of an inner tube, to contain the solution, about 3^{cm} in diameter and 20^{cm} long, graduated up to 30^{cc} from below, and contained within an outer tube 6^{cm} in diameter and about the same length. Through a stopper in the inner tube passes a thermometer and a tube to convey the vapor of the solvent, both going to the bottom. This vapor, generated in a side flask, passes through the solution in the inner tube, thence through a small hole near its top into the outer tube and on to the condenser. To fix the boiling point of the solvent, about 12^{cc} of it are placed in the inner tube, and its vapor is then conducted through it from the flask until drops fall from the condenser at the rate of one every two seconds or so, when the thermometer is read. The tube is then transferred to an upright cylinder which it just fits and the volume of the solution is read to tenths of 1^{cc}. About half of the liquid is now poured off and from half to one gram of the substance under examination is added to the remainder in the tube. The vapor is then passed through this as before, the thermometer is again read and the volume measured. The latter operation may be repeated half a dozen times and the mean taken. The result may be calculated by the formula

$$\text{Mol. mass} = \frac{\text{Constant} \times \text{mass of substance}}{\text{Elevation} \times \text{volume of solution.}}$$

The constants for the various solvents are obtained simply by dividing the ordinary weight-constants of these liquids by their densities at the boiling point. Since only one weighing is needed much time is saved, six determinations requiring only a half hour. The volume need be read only to $0{\cdot}1^{cc}$ and the thermometer only to fifths of a degree. Alcohol or ether should preferably be used as the solvent, though acetone gives good results when pure. Values obtained with various substances in various solvents are given which show that the accuracy of the method is quite suffi-

* Ber. Berl. Chem. Ges., xxxi, 458, March, 1898.

cient for ordinary preparatory or research work in organic or inorganic chemistry.—*J. Chem. Soc.*, lxxiii, 502–511, June, 1898.

G. F. B.

4. *On the Chemical Effects of the Silent Electric Discharge.*—An elaborate series of experiments has been made by BERTHELOT on the chemical effects of the silent electric discharge, having reference specially to the union of nitrogen with compounds of carbon. The mixture under examination was enclosed in a narrow space about a millimeter wide, through which passed the discharge from a coil having a Deprez contact-breaker and including a Leyden in circuit. The sparks were 12 to 15^{mm} long, the discharges being alternating. They were kept up generally for 24 hours. If the vapor pressure was high the liquids behaved like gases, but if low the reaction was slow. The intermediate products when examined were found to differ considerably from the final products. While the speed and nature of the reactions seem to be functions of the intensity of the discharge, actual sparking should be avoided. Final equilibrium depends in general upon the production of solid or resinous products having a low vapor pressure and a low conductivity. When nitrogen is absorbed the product resembles an amine or an amido derivative, being often a poly-amine. Methane thus treated gives up half its hydrogen, yielding a solid body $C_{10}H_{18}$. If nitrogen be present, it is absorbed in amount rather less than one-quarter of the volume of the hydrogen set free, giving a solid body $C_2H_3N_1$, alkaline to litmus and probably a tetramine. Ethane loses a third of its hydrogen and yields the same condensation product; while in presence of nitrogen, the solid produced $C_{16}H_{32}N_4$ is analogous to that from methane. Ethylene condenses to a solid C_8H_{14}; while with nitrogen the volume of this gas absorbed is substantially equal to that of the hydrogen set free, and the resulting alkaline solid is the same as with ethane. Acetylene yields first a liquid and then a solid which when heated is decomposed with explosion and oxidizes rapidly in the air. With nitrogen the solid product $C_{16}H_{16}N_2$ is obtained. Propylene alone yields a solid $C_{15}H_{26}$ and with nitrogen a whitish resin $C_{15}H_{28}N_4$. Carbon monoxide is converted into carbon dioxide and the sub-oxide C_4O_3; and into a brown solid forming an acid solution when dissolved in water. With hydrogen in excess, the gases condense in equal volumes, giving $(CH_2O)_n$, a mixture of polymers of formaldehyde. With hydrogen and nitrogen, a condensed formamide $(CH_3NO)_n$ results. Carbon dioxide alone gives percarbonic oxide and the above sub-oxide. Mixed with two volumes of hydrogen, a carbohydrate is formed similar to that given by the monoxide. With one volume of nitrogen and three of hydrogen a residual gas is obtained consisting of equal volumes of nitrogen and hydrogen; and also a solid product which when heated with water gives an effervescing solution containing ammonium nitrite, and which may be considered as a compound of this substance with the amido compound given by the monox-

ide. The author compares this action of the electric discharge to the interactions of water and carbon dioxide in plants. Similar interesting results were obtained with the alcohols and ethers, ethyl alcohol giving a solid $C_{16}H_{30}N_4O_6$.—*C. R.*, cxxvi, 561, 567, 609, 616, February, 1898. G. F. B.

5. *On a New Gas.*—At the Boston meeting of the American Association, C. F. BRUSH announced the discovery of a new gas, a constituent of the atmosphere and presumably elementary. Its chief characteristic is its enormous heat conductivity at low pressures. In studying the heat conductivity of several gases in high vacua, early in 1897, he had observed that pulverized glass when heated evolved a considerable quantity of absorbed gas. And making use of his heat-conductivity method to detect the hydrogen present, he was surprised to find that at 36 millionths pressure the residual gas conducted heat twice as well as air and nearly as well as hydrogen; while at 3·8 millionths it conducted seven times, at 1·6 millionths, fourteen times, and at 0·96 millionth, 20 times as well. Under this latter pressure the time taken for the thermometer to cool from 15° to 10° was only 177 seconds; pure hydrogen requiring 288 seconds. Upon exposure to the air the glass reabsorbed the new gas. Upon subsequent investigation other porous materials were found to answer the same purpose. Charcoal made from pine-wood sawdust and highly heated evolved the new gas. Fine white siliceous sand when heated in vacuo also gave it, the conductivity at the pressure of 0·12 of a millionth being 42 times that of hydrogen. To free this new gas from the gases mixed with it, diffusion through a treated porcelain tube was resorted to. Under a pressure of $1·3^{mm}$, about 19^{cc} of gas diffused per hour. And after 36 hours the diffused gas being tested showed at 6 millionths a higher conductivity than the specimen last mentioned for the same pressure; the heat conductivity of air therefore seems increased a hundred times, at very low pressure, by one diffusion. Since even when mixed with other gases, the heat conductivity of the new gas at very low pressures is 100 times that of hydrogen, the author thinks that when pure it may become a thousand times greater. Supposing the molecular speed to be proportional to the heat conductivity, the molecular speed of the new gas would be at least 100 times that of hydrogen, or 105 miles per second. Moreover as the molecular velocities vary inversely as the square root of the densities, the density of the new gas is only the 10,000th part of that of hydrogen or the 144,000th part of that of air. It should therefore extend 144,000 times as high as the air and hence must extend indefinitely into space. If, as is probable, less than a millionth of it is contained in the atmosphere, then it seems likely "that it not only extends far beyond the atmosphere but fills all celestial space at a very small pressure." Hence the author, assuming the new gas to be elementary, has given it the name "*Aetherion*," and supposes its molecule to be monatomic. He ventures the conjecture that it will be found to be a mixture of three or more gases, all

very much lighter than hydrogen.—*Abstract of paper communicated to this Journal by the Author.*

6. *Electricity and Magnetism; a Mathematical Treatise for advanced undergraduate students;* by FRANCIS E. NIPHER, A.M. 2d ed., revised with additions, 8vo, pp. xii, 430. St. Louis, 1898. (J. L. Boland Book and Stationery Co.)—Professor Nipher has succeeded in producing a text-book admirably adapted for higher class room work and we are not surprised that a new edition should so soon be called for. He tells us that he has made an attempt in it "to avoid wasting the time of the reader over puzzles and obscurities which are made difficult and called easy." In this edition, he gives in the preface reasons for the treatment he has adopted and says: "It is for such reasons that the author has determined not to be guided by those of his reviewers who seem to think that the time of the student should be spent in rapidly acquiring a set of rules by means of which electrical machinery may be designed. The great advances in engineering have been made by those who applied their brains to useless things and made them useful. This is a sufficient reason why the engineer should be first of all a student." G. F. B.

7. *Electrical currents excited by Röntgen rays.*—It has been shown by various observers that these rays can dissipate electrical charges. A. WINKELMANN shows that they can also charge bodies. He states that J. Perrin (Comptes Rendus, cxxiv, p. 496, 1897) has also proved this independently and has arrived at practically the same result. Winkelmann, however, goes on more exhaustively to show that the air between the source of the X-rays and the charged body is broken up into ions; and he measures the ohmic resistance of different layers of air thus ionized. The method of studying the resulting charges consisted in charging a condenser by the rays and in discharging this through a ballistic galvanometer. The sensitiveness of the galvanometer was such that the discharge of one microfarad charged with 0·032 volt gave a deflection of 2^{cm}. An electrometer was also used. It was shown that the electrical charges on plates of different metals were not produced by the direct effect of the X-rays but were the result of the ionizing of the intervening air; for the plates could not be charged when they were coated with a layer of varnish which was permeable to the X-rays. If we adopt the hypothesis that the charging is due to the ions conveying charges, we find that the changes in resistance of the intervening air is explained: for this resistance depends on the number of ions in the unit of volume. This resistance was found to depend on the intensity of the Röntgen rays; on the number of breaks of the induction apparatus per second, and between plates near together, on the resistance in the current circuit. The specific resistance of air can thus vary greatly under the influence of the rays. The proportion of ionized molecules to the whole number of molecules in the unit of volume was found to be $4{\cdot}6 \times 10^{-13}$. This is the same order of magnitude as the result obtained for hydrogen by Prof. J. J. Thomson.—*Wied. Ann.*, No. 9, pp. 1–28, 1898. J. T.

8. *Reflection of Cathode rays.*—H. STARKE proves by a method which he believes to be superior to those hitherto adopted, that cathode rays are reflected in different degrees by different metals. At perpendicular incidence, platinum reflects 36 per cent. This proportion does not change appreciably with changes of charging potential from 6000 volts to 9000 volts.—*Wied. Ann.*, No. 9, pp. 49–60, 1898. J. T.

9. *Change of the energy of Cathode rays into light rays.*—E. WIEDEMANN measures the proportion of energy of the cathode rays which is converted into light rays and finds that the proportion converted into light is of the same order as that in the case of photoluminescence and is very small.—*Wied. Ann.*, No. 9, pp. 61–64, 1898. J. T.

10. *The Theory of the Coherer.*—Since the discovery of Branly that electrical waves can diminish the resistance of tubes filled with fine metallic particles, many investigators have endeavored to ascertain the cause of the phenomenon. The recent experiments in wireless telegraphy have given great interest to this inquiry. D. VAN GULIK reviews the various theories proposed, and in view of his own experiments inclines to the belief that the action is due to minute sparks between the particles, which break down the separating oxide or intervening medium, and the torn off particles resulting from the disruptive sparks build a conducting bridge. He objects to the new term "Frittröhren" introduced by Slaby.—*Wied. Ann.*, No. 9, pp. 136–145, 1898.

E. DORN has carried out a very complete series of experiments to test the theories of the coherer. The degree of moisture of the pulverized substances greatly affected the results. Oxides of iron, of zinc and of copper appeared to possess the greatest conductibility; aluminum and its oxides the least.—*Wied. Ann.*, No. 9, pp. 146–161, 1898. J. T.

11. *Absorption of light produced by a body placed in a magnetic field.*—AUGUSTE RIGHI discusses phenomena of absorption due to the Zeemann effect. A beam of light from the sun or an electric light is polarized by a nicol prism and sent through the axis of a powerful Ruhmkorf magnet. This beam is extinguished by a second nicol. Between the poles of the magnet is placed a sodium flame. The yellow light is not extinguished on turning the analyzer; on the contrary it becomes white and more and more intense. The author discusses the theory of the experiment from the point of view of Zeemann.—*Comptes Rendus*, July 25, 1898, p. 217. J. T.

II. GEOLOGY AND MINERALOGY.

1. *18th Annual Report of the Director of the U. S. Geological Survey, 1896–97* (Extract from 18th Ann. Rept., Pt. I), C. D. WALCOTT, Director; pp. 1–130, two folded maps. Washington, 1897.—During the year covered by this Report the sum of $568,690 was appropriated for the work of the United States

Geological Survey. The new work of establishment of permanent monuments resulted in running 10,840 miles of levels and establishing 1820 bench marks. Provision was made, by the sundry civil bill approved June 4, 1897, for the survey of the northern portion of the boundary line between Idaho and Montana, the first work of the kind assigned to the Geological Survey. Provision was also made, with an appropriation of $150,000, for the survey of the forest reserves. Progress was made in this direction, specially in South Dakota, Wyoming, Montana and Washington.

The preparation of educational series of rocks was completed and their distribution to educational institutions begun. For the purpose of assisting the director in the internal work of the Survey, advisory committees were established in petrography and chemistry, and Mr. Bailey Willis was appointed assistant to the Director in geology. The main branches of work of the Survey were continued along the lines of previous years with the accustomed energy and abundant results, a summary of which is given in the report. H. S. W.

2. *Summary Report of the Geological Department of Canada for the year 1897*, G. M. DAWSON, Deputy Head and Director; pp. 1–156. Ottawa, 1898.—Among the numerous items of interest of which a general summary is given here, attention may be called to the following: The experimental borings in Northern Alberta, at the mouth of the Pelican River and at Victoria on the Saskatchewan, have resulted in the discovery of the "tar sands" in the Pelican River boring, at the depth of 750 feet. Here maltha, or heavy, tarry petroleum was met with, and at 820 feet an exceedingly heavy flow of natural gas under high pressure was struck. These rocks, it will be remembered are of Cretaceous age. In the Victoria well only the dark overlying shales have yet been penetrated, to a total depth of 705 feet.

The investigation of Dr. Adams and Mr. Barlow in the Haliburton region bear out the conclusions of former work in showing that the Fundamental gneiss consists of granitoid-gneissic rocks in the form of great batholitic masses, the limestones, etc., of the Grenville series sagging down between and wrapping around the batholites as great mantles. These gneissic rocks, in parts of the area, have become more completely molten and have developed into truly intrusive granites which no longer merely arch up the overlying strata but break through and cut across them.

Interesting results were obtained by Mr. Chalmers in tracing the Pleistocene shore lines of the St. Lawrence Valley. The traverse extended from Orleans Island westward to Lake Ontario and to Lake Nipissing. From his observations Mr. Chalmers concludes that the general upheaval of the St. Lawrence basin in the Pleistocene period was differential throughout, increasing to the westward. The greatest upheaval seems to have been immediately to the northeast and north of the Great Lakes, and the maximum heights there will probably be found to be represented

by a number of axes, or uplifted belts, not always in the same direction, but conforming more or less to the longer axes of these great bodies of water. The period at which this great upheaval of the region took place appears to have been that of the deposition of the Saxicava sands, or rather during the latter part of that period.

Regarding the Carboniferous Flora of Nova Scotia, Mr. Whiteaves reports that "the fossiliferous sandstones and shales of the Union and Riversdale regions in Colchester and Pictou counties, are seen to lie unconformably beneath the fossiliferous marine limestones, sandstones and shales of Lower Carboniferous age. They hold plants and animals which in their broad general characters resemble those of the eastern American Carboniferous —if we leave out of consideration the types which occur in the 'fern-ledges' of Lancaster county in New Brunswick, described and regarded as Devonian. The fossils which show this affinity to types of Carboniferous age include, besides the presence of a protolimuloid crustacean closely allied to *Prestwichia* and erect trees of doubtful affinities, such genera as: *Calamites*, *Asterophyllites*, *Alethopteris*, *Sphenopteris*, *Cyclopteris*, *Cordaites*, *Spirorbis*, *Naiadites*, (*Anthracomya*), *Lepidodendron*, *Leaia*, *Carbonia*, *Estheria*, *etc.* All these have been found in the Riversdale and Union rocks, and the following species are common to these rocks and those of Lancaster county, New Brunswick: *Cyclopteris* (*Aneimites*) *Acadica*, *Lepidodendron corrugatum*, *Stigmaria ficoides*, var., *Cordaites Robbii*, (sometimes with numerous specimens of *Spirorbis* covering the surface of the leaves,) besides closely related forms belonging to the genera *Calamites*, *Asterophyllites*, *Alethopteris* and *Sphenopteris*. From this it would appear that the strata of Union and Riversdale may be regarded as equivalent to those in Lancaster county, which have been described and held to be of Devonian age." H. S. W.

3. *The Geological History of the Isthmus of Panama and portions of Costa Rica.* Based upon a Reconnoissance made for Alexander Agassiz; by ROBERT T. HILL. Bull. Mus. Comp. Zool., Harv. Coll. Vol. xxviii, No. 5, pp. 151–285, figs. 1–24, plates i–xix. June, 1898.—A notice of this important paper is deferred until another number.

4. *The physical geography of Worcester, Mass.;* by JOSEPH H. PERRY; pp. 1–40, plates i–viii. 1898.—A popular description of the surface features about Worcester, illustrating the drumlins and other evidences of glacial action. The plates are reproductions of photographs finely prepared by J. Chauncey Lyford, the whole doing credit to the Worcester Natural History Society, which publishes the paper. H. S. W.

5. *Handbuch der Mineralogie;* von Dr. CARL HINTZE. Erster Band, Zweite Lieferung, pp. 161–320. Leipzig, 1898 (Veit & Company).—The second part of Volume I of Hintze's Mineralogy (No 14 of the entire series) has just been issued. Its hundred and fifty pages are devoted to descriptions of native iron, copper,

silver, and gold. These subjects are treated, as is implied in this statement, with admirable fullness, particularly with reference to the geographical distribution, and liberal illustrations are introduced whenever called for. Mineralogists will be gratified to see this great work gradually drawing on toward completion.

6. *Manual of Determinative Mineralogy with an Introduction on Blowpipe Analysis;* by GEORGE J. BRUSH. Revised and enlarged, with entirely new tables for the identification of minerals, by SAMUEL L. PENFIELD. Fifteenth edition, pp. x, 312. New York, 1898 (John Wiley & Sons).—The thorough revision which Prof. Penfield has now given to Brush's Determinative Mineralogy completes the work begun by him two years since. In the edition of 1896 (this Journal, ii, 459, 1896) the opening chapters descriptive of the blowpipe and chemical methods and reactions applicable to minerals, were carefully rewritten and made to embody the practical results of the author's long experience in teaching. At the present time this introductory portion of the work has been further improved by the addition of a chapter upon crystallography and the physical characters of minerals, in which these subjects are concisely but clearly presented. More important than this, the determinative tables have now been rewritten, rearranged and enlarged so as to include all recently described species of definite character. The changes which have been made here are fundamental and highly important for the student, since in their present form the tables show with admirable distinctness the fundamental differences in chemical composition which form the basis of the grouping of the species. Hence the student who uses the tables intelligently is sure to learn a vast deal in regard to minerals, especially on the chemical side. Their value is much increased by the fact that in the case of most species the author has personally verified the reactions described.

For nearly twenty years this admirable work has held a place of its own and has played a highly important part in scientific education. In its new form, with the changes and additions which bring it into harmony with the science of the present time, it cannot fail to be still more appreciated and to find even a wider sphere of influence.

7. *The Law of Mines and Mining in the United States;* by DANIEL MOREAU BARRINGER and JOHN STOKES ADAMS. Pp. cxxv and 878. Boston, 1897 (Little, Brown & Company).—All those interested in the legal questions which are likely to arise in regard to mining properties will appreciate the value of the admirable and exhaustive treatment of the subject in the present volume. It opens with a table of cases referred to through the text; then follows an excellent geological preface designed to make the non-scientific reader acquainted with the different types of deposits and the conditions under which they occur. This is abundantly illustrated by figures drawn from well-known authors. The work proper is divided into twenty-five chapters, classified according to the special subjects discussed. An appendix gives

the United States statutes and land office regulations, dealing with the mineral lands, timber rights, privileges of miners, etc.

8. *Canadian minerals.*—In Part R of vol. ix of the Annual Report of the Geological Survey of Canada, Dr. G. CHRISTIAN HOFFMANN continues his investigations of Canadian minerals. Among the new occurrences noted, the following may be mentioned: Baddeckite, a ferruginous muscovite from Baddeck, Nova Scotia (this Journal, vi, p. 274); chalcanthite, and argentiferous tennantite, from the Avoca claim, Lillooet district, British Columbia; xenotime from Calvin township, Ontario, in a crystalline mass weighing 312 grams; gahnite from Raglan township, Renfrew Co., Ontario; gersdorffite in octahedral crystals from Kootenay Mountain, near Rossland, British Columbia.

OBITUARY.

JAMES HALL.

Even the chief traits and accomplishments of this remarkable man would demand a longer space than is available for this notice, and therefore only a few salient characteristics and events will here be mentioned. His strength and even his weaknesses, his successes and his failures were of an extent seldom combined in a single individual existence. In years of activity also, he covered a period almost unparalleled for its length. Extreme longevity combined with persistent continuity of purpose, and the vast resources of the state of New York, must be accounted as a leading factor in any consideration of the scientific monument which this man erected for himself, and for which, in addition to personal work, contributions were levied from among several generations of assistant co-workers. The magnitude of the private and public collections accumulated at Albany, the large sums spent for their investigation, and the elaborate publication of results, together with the amount and variety of the investigations carried on, attracted the rising and ambitious paleontologists of the United States to Albany for many years. This enabled the State Geologist to equip himself with some of the best talent in the country, and in a considerable degree determined the quantity and character of the output of his department. The names of Gabb, Hayden, Meek, Whitfield, Walcott, Beecher, Clarke, Schuchert, and others will serve to illustrate this point.

As a lobbyist among over sixty annual legislatures he held a unique position in the State. In his successful adjustments to the kaleidoscopic and bewildering political complexion of this long period is shown his wealth of resource and adaptability. In his managerial skill and tireless energy he was alone and without a peer.

In the present connection, his accomplishments in the domain of science are of chief interest, but in any estimate of this his relations to the state and its scientific staff must not be lost sight of. With the possible exception of Barrande in Bohemia, no one has made known to the world so many extinct forms of animal life from the Paleozoic System. This work forms the bulk of the famous series of quartos known as the "Natural History of New York," and is generally referred to as the "Palæontology of New York." Besides this voluminous work Hall published a great many memoirs and smaller papers in the annual reports of the State Museum, the reports of the State Geologist, in the proceedings of learned societies, and in various scientific journals. Altogether, in the description of new genera and species of Paleozoic invertebrates his work forms the main structure around which similar work of other states cluster, and upon which other investigators have built. His energies were not wholly confined to the limits of New York, for in 1855 he was made the State Geologist of Iowa; and in 1857, he held a similar position in Wisconsin. Many of his papers were based upon material from other parts of the continent, especially Ohio, Indiana, Illinois, Kentucky, Tennessee, Minnesota, Pennsylvania, Michigan, and Canada.

As a field geologist his best work was derived from a study of the Paleozoic sediments later than the Cambrian. His correlations of the New York formations with those of the Mississippi Valley and with Europe were of prime importance and helped to make geology more than a provincial science.

In the year following Dana's address on the origin of continents, delivered in 1856 at the meeting of the American Association for the Advancement of Science, Hall proposed, on a similar occasion, his theory of mountain-building by previous regional subsidence, and maximum accumulation of sediments. Both of these theories have since become generally recognized.

James Hall was born at Hingham, Mass., Sept. 12th, 1811. He was graduated from the Rensselaer Polytechnic Institute at Troy, New York, in 1832, and continued his services there for some years as professor, first of Chemistry and Natural Science, and later of Geology. In 1842 he received the degree of M.A. from Union College, and that of LL.D. from Hamilton in 1863, and McGill in 1884. He joined the organization of the Geological Survey of the State of New York in 1836, and remained in continuous service up to the time of his death, which occurred August 7th, 1898.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XLIV.—*Another Episode in the History of Niagara Falls*; by J. W. SPENCER.

[Read before American Association for the Advancement of Science, August, 1898.]

CONTENTS:

Summary of the Changing Physics of the River.

FOUR years ago, a paper was presented by the writer to the American Association for the Advancement of Science,* computing, for the first time, the age of the Falls, as based upon the changing episodes of the river. The data upon which the computations were made embraced not only the measurement of the modern rate of the recession of the Falls, but also the discoveries: (1) that the Niagara River did not formerly drain the Algonquin (Superior-Michigan-Huron) basin (which then emptied towards the northeast)†; (2) that the river for a long

* "Duration of Niagara Falls," by J. W. Spencer, this Journal, vol. xlviii, pp. 455–472, 1894.

† Mr. F. B. Taylor has stated that the "original hypothesis" of "a northern way of discharge of the upper lakes" was first suggested by Mr. G. K. Gilbert in 1886 (Bull. Geol. Soc. Am., vol. ix, p. 80, 1898). But it is manifest that Mr. Taylor is laboring under a misapprehension. The discovery of the evidence and the announcement of the hypothesis that the drainage of the uppermost three lakes was diverted from the Niagara River, by the discharge of their waters towards the northeast, was first communicated by the present writer to the meet-

time descended only 200 feet in place of 326 feet, as to-day; (3) that Foster's flats recorded the amount of recession of the Falls during the earlier stages, when the Erie waters alone drained through Lake Erie, and cascaded over a diminished fall; (4) that when the Falls had receded to Foster's flats, all the drainage of the upper lakes was turned into Niagara River; (5) that again the descent of the river was increased to 420 feet (as first shown by Prof. G. K. Gilbert), which increase gave rise to a succession of cascades, after which the height was supposed to have been directly reduced to the present level. The most important and continuous of these cascades was that over the Medina sandstone, still represented by rapids; and it may be most properly named the Gilbert Falls.

These changing conditions in the physics of the river necessarily greatly modified the rate of recession of the Falls, and from their considerations, a new determination of their age became necessary. These calculations were only a stepping stone towards ascertaining the age of the Falls, and each addition to our knowledge of the various phases of the river will enable us to approach a more accurate computation of the duration of the Falls. There was also brought to light for the first time a means of determining the rate of the upward movement of the earth's crust, and the evidence of the extinction of the Falls by the diversion of the waters of all the upper lakes into the Mississippi by way of Chicago.

However, all the physics of the river were not satisfactorily explained. Thus the section of the cañon, about 4,300 feet* long, at the Whirlpool Rapids, is the narrowest and shallowest part of the gorge, not explicable by a changing character of the rock. Even the provisional explanation of the writer was not satisfactory to himself, and accordingly another was offered by Mr. F. B. Taylor, which will be noted later. Subsequently, Prof. Gilbert estimated various depths of the river channel,†

ing of the American Association for the Advancement of Science in 1888, of which an abstract appeared in the Proceedings of the Society for that year.

That which Mr. Gilbert had written was as follows: "The rate" (of recession of the Falls) "may also have been influenced . . . by variation in the amount of its volume" (i. e. of the Niagara River) "due to change of climate or catchment basin. The catchment basin was formerly extended by including parts of the area of the ice sheet. It may have been abridged by the partial diversion of the Laurentian drainage to other courses" (Proc. A. A. A. Sc., vol. xxxv, p. 223, 1886). This is the entire statement, implying the possibility of changes of outlet in any direction being a subject for consideration, and does not advance the discovery or hypothesis as stated by Mr. Taylor, although it announces the hypothesis of an increased discharge from glacial waters.

* Originally only a length of 4,000 feet was taken.

† See American Geologist, vol. xviii, pp. 223, 1896. The maximum depth of the river had been found by soundings to reach 189 feet in the basin just below the modern falls; and 96 feet in depth immediately outside the end of the gorge. Mr. Gilbert estimated the depth of the whirlpool rapids at 35 feet; of the whirlpool, 150 feet; of the channel at outlet of whirlpool at 50 feet; of the basin

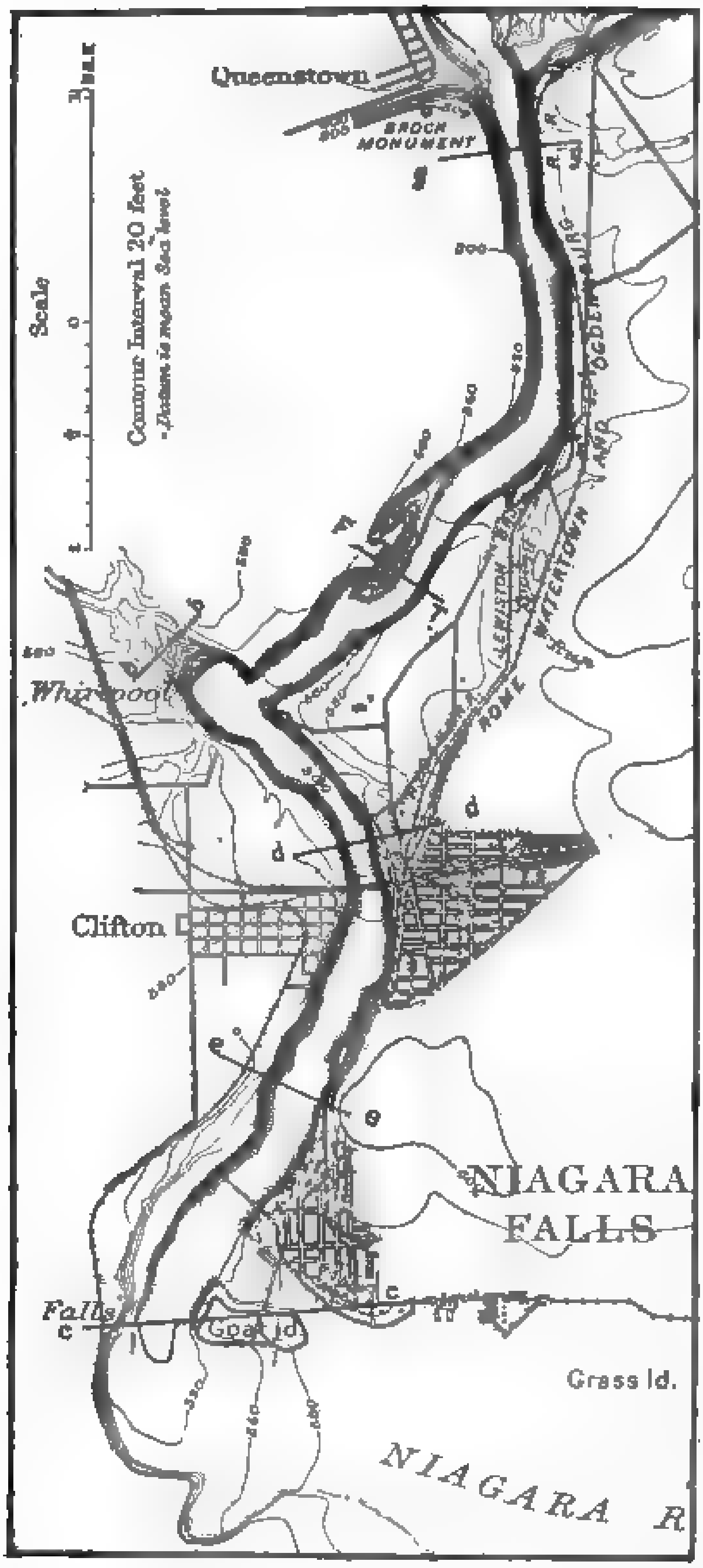


FIGURE 1. Map of the Niagara gorge, showing its variable width. F, location of Foster's flats. The thin (560 feet) contour line on each side of the section above Foster's flats has been found to nearly coincide with the banks of the river before the waters sunk within the gorge, thus showing that the breadth of the river was not diminished at the Narrows until after the excavation of the gorge through Johnson's ridge. (*ee*) crossing the course of the river between the upper bridge and the town of Clifton.

where actual surveys could not be effected. Recognizing that the peculiar feature of the gorge at the Whirlpool Rapids

immediately above Foster's flats at 100 feet, while the rapids in front of Foster's flats are reduced to 35 feet, and then the channel increases to 70 feet before passing out of the cañon section.

recorded some change in the history of the river, the writer set to work to enquire why the channel appeared to be scarcely more than about 35 feet deep, while above it, nearer the Falls, its depth reaches to from 160 to 189 feet. This investigation has led to the discovery of an important episode in the history of the Falls, namely, that after the river reached its maximum descent of 420 feet, the surface of Lake Ontario was gradually raised 75 feet above the present level, and the waters stood in the Niagara gorge so as to reduce the descent of the river to 250 feet, before the final lowering of the Ontario waters to a level of 326 feet beneath those of Lake Erie. This discovery will be found to explain the greater shallowness of the channel at the Whirlpool Rapids than below or above.

Revision of the Episodes of Niagara River.

As previously described,* the first episode of the river was characterized by a cascade comparable in size to the American Falls, draining the Erie basin alone (whose discharge is only between one-fourth and one-sixth† that of the basins of the four upper lakes), and descending 200 feet into the lower lake, then at the level of the Iroquois beach. This condition prevailed until the cataract had receded about 9,000 feet‡ from the mouth of the gorge§ (see figure 1).

The commencement of the second episode was marked by the increase in the volume of the water, owing to the drainage of all the upper lakes being turned into the Niagara. This caused the river to broaden its channel so that the cañon, along the section of Foster's flats (F, fig. 1) and for some distance above, is much wider than below. But the height of the Falls was not increased until after they had receded a further distance of 6,300 feet,‖ when Foster's flats had been passed. That the height was not increased is shown by the fact that the flats represent the floor of the channel at that time,

* See Duration of Niagara Falls.

† The discharge was measured by the Corps of Engineers, U. S. A. Report for 1869, p. 582. In the early part of the season, when the summer drainage was coming from the upper lakes, the discharge of the Erie basin was 16·3 per cent that of all the four lakes. Later in the season the discharge of Erie increased to 28·9 per cent. The mean discharge was 22·5 per cent. Consequently it would be better to accept this proportion in place of approximately one-fourth.

‡ Originally taken to the foot of Foster's flats, 11,000 feet; but now to only where the gorge widens, near the Catholic College, for it appears that the lower part of the flats have been denuded away.

§ This section of the modern river has reoccupied the extension of the buried shallow preglacial depression or valley of Bloody Run, and this in part explains the change of course and the narrowness of this lower section.

‖ The best development of Foster's flats is 3,000 feet long, which measurement was originally used, but the full length is about 3,700 feet, to which length is now added a section of 2,600 feet of the cañon below, with a corresponding breadth.

although this floor is now from 35 to 50 feet above the level of Lake Ontario; with the remains of a terrace considerably higher. The rugged features of the upper part of the flats indicate a transition stage. Had the descent of the river been increased to the maximum at this time, the excavating power of the Falls should have cut its channel deeply in the rock beneath the floor, of which Foster's flats is a remnant. The correctness of this conclusion is shown by the deeper (see section, fig. 2) and wider channel above this section. The great power of excavation during the full height of the Falls is also illustrated just below the present cataract, where the thick bed of hard Medina sandstone, the same as at Foster's flats, has been more than penetrated by the impact of the water, although this hard bed is far beneath the surface of the river. The upper end of the flats (see F, fig. 1) marks the closing of the episodes of the first inferior descent of the river.

The excavation of the deep basin between the head of Foster's flats (see fig. 2) and the whirlpool shows the amount of work performed by the Falls during the next episode, when the descent of the full volume of the river was increased from 200 to 420 feet; but of the increased descent probably quite 170 feet* was situated in the lower part of the gorge and its extension to the retreating shore line of Lake Ontario, when the channel below the end of the gorge was excavated to a depth of a hundred feet below the present surface of the lake. It was the Medina sandstone, now exposed, which gave rise to a distinct cascade, before mentioned, occurring two and a half miles below the front of the main falls. This lower cataract, with an interrupted history, has not yet completed its work, although it has cut the modern secondary cañon through Foster's flats, having a width reduced to only 380 feet† with vertical walls from 40 to 50 feet high. Here the river is estimated at 35 feet deep, although it greatly increases in depth below the flats. This portion of the river is still characterized by heavy rapids.

While the main cataract was descending over Niagara limestone, just above Foster's flats, and the lower or Gilbert Falls cascading nearer the mouth of the gorge (see section, fig. 2), there seems to have been an intermediate fall from the harder beds of the Clifton rocks; but as these do not give rise to a separate cataract to-day, there does not appear any reason to suppose that the intermediate cascade continued

* The floor of Foster's flats was 130 feet above the lake level as established when the Niagara River descended 420 feet, with the estimated depth of water in this portion of the cañon reaching 40 feet above it, or the descent of the lower fall and rapids amounted to 170 feet.

† Surveyed by an engineer for Mr. George Holley.

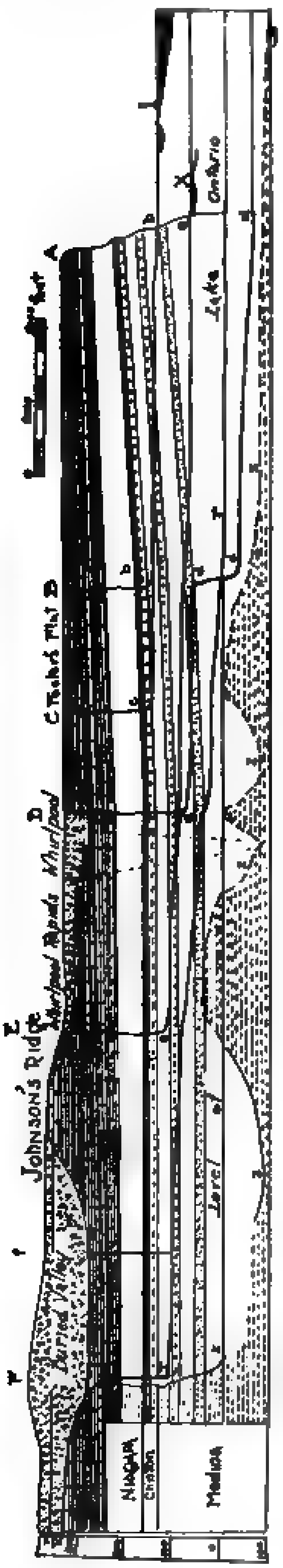


FIGURE 2. LONGITUDINAL SECTION OF NIAGARA GORGE, showing the floor of the channel on (shaded) Medina shale, and the theoretical position of the Falls and profile of the river at the end of each episode—(1) *Bbb*, (2) *Ccb*, (3) *Dddd*, (4) *Eee*, *Err*. F, site of modern falls; I, position of the Iroquois Beach; X, position of the Niagara Beach; *xxx*, the three deep basins. Foster's flats are located on the (dotted) band of Medina sandstone at 35–50 feet above the lake. A similar remnant occurs at outlet of whirlpool. Johnson's ridge is a rocky barrier in front of the broad preglacial valley.

long to be an important feature, although remnants of terraces corresponding to its height are traceable at Foster's flats, at the mouth of the whirlpool, and perhaps a few hundred feet above this point, near the foot of the Whirlpool Rapids upon the eastern side.

This epoch of maximum volume and descent appears to have been of short duration, as the deep channel above Foster's flats is only 3,200 feet in length, and is limited by the barrier at the outlet of the whirlpool (fig. 2), which is a later remnant of a river floor similar to that of the flats below. The same hard Medina ledges are exposed as far as the foot of the Whirlpool Rapids. The deeper cauldron of the whirlpool behind its contracted outlet occurs only as an incident in the excavation of the gorge, for, in part, it was the site of a short fragment of an ancient buried channel, and it is not a record of the changing episodes of the modern Niagara. The occurrence of the rocky ledge, at the mouth of the whirlpool, indicated that the maximum descent of the river was reduced when the Falls reached this point. The dissection of this ledge by a channel, only 400 feet in width and 50 feet in depth, is the work of the modern restoration of the lowest cataract, which was interrupted as will be explained later.

The Newly-discovered Episode—the Niagara Strand.

The closing part of this last episode, and the next, during which the Falls receded to a point above the Narrows (fig. 2) of the Whirlpool Rapids has proved the most difficult of explanation. The writer provisionally adopted* a hypothesis by which the maximum height of the Falls was continued throughout this section. But the recent investigation shows that during this time the descent of the river was reduced from 420 to 250 feet, before it was increased to the present amount of 326 feet. Consequently, in the earlier writings upon the history of the Falls, this important episode, and its effect upon the Falls, were unknown.

Below Foster's flats, the sloping sides of the gorge are covered with talus, while the section passing the flats is that of a newly formed cañon with vertical walls, except at the foot (showing a transition stage). Opposite the lower end of the flats, there is a delta deposit of river stones, some of which are more or less subangular, forming a sort of terrace within the cañon, rising to a height of 70–75 feet. Its occurrence shows first the excavation of the gorge, and then the rise of the waters in it to the named height, so as to have allowed the accumulation of the deposit. The evidence of this rise of the river is further demonstrated by the occurrence of terraces immediately below the end of the gorge, having a height of 50–55 feet, on which there is a beach-like gravel ridge at an elevation of 70–75 feet above Lake Ontario. This terrace with its surmounting ridge is here named the Niagara Strand. The further sinking of the water is shown in the terraces at about 35 feet, and at 5–10 feet. The rising of Lake Ontario to a height of 75 feet would back the surface of the river to not merely the whirlpool, but had the cañon been excavated, it would have extended the lake level to about the point of the inclined railway (opposite the middle of Whirlpool Rapids). This backing of the waters would naturally protect the floor from erosion, and would explain the shallowness of the section of the Whirlpool Rapids. The amount of work performed by the Falls during this episode of reduced descent of the river is represented by the excavation of the cañon for a distance of 6,800 feet,† to a point just above the railway bridges, figure 2 (less that portion of the rock which had been removed from the valley in preglacial times). The narrowness of the gorge at the Whirlpool Rapids will be considered later.

* See Duration of Niagara Falls, cited before.

† Of this distance, 2500 feet is the portion of the section between the Medina sandstone barrier at the outlet of the whirlpool and the foot of the rapids above, while through the Narrows the length is 4300 feet.

The Modern Episode.

The last episode, or that of the present day, is characterized by the waters sinking again, so that the descent of the river has been increased, and now amounts to 326 feet. But this change was not continuous, for the descent was 350 feet or somewhat more, while the falls were receding through Johnson ridge (see fig. 2), back of which there was a preglacial valley 90 feet deep, that upon being reached by the falls, caused the waters to be lowered to the present amount. The dissected rocky ridge is 4,800 feet across before reaching the buried valley behind it (at a point near the upper bridge). Here the river channel has a depth of 160 feet, although above the shallow Whirlpool Rapids. Since passing this Johnson's ridge the Falls, with their height as now seen, has receded a further distance of 6,400 feet—thus completing a section of 11,200 feet during the modern episode of two stages. The mean recession of the Falls is now $4\frac{1}{6}$ feet a year.

With the last increase in the descent of the river, the lowest or Gilbert cascade was reëstablished, of which remnants occur in the rapids at Foster's flats and at the outlet of the whirlpool.* The more shallow channel of the Narrows has also given rise to an intermediate cascade in the form of the Whirlpool Rapids, with the descent of about 60 feet.

The Rise of the Ontario Waters.

Further evidence of the backing of the waters in the Ontario basin may be seen in the former lagoon, behind Burlington heights, at the head of Lake Ontario, where the gravel beds of the Iroquois Beach epoch have been eroded and subsequently covered by silt. This deposit of from four to eight feet in thickness was accumulated in the quiet waters of a protected bay when Lake Ontario stood at about 70 feet above its present level, at which height it forms a conspicuous terrace and plain.

The Niagara Strand is well marked in the small embayment behind the Iroquois Beach at the outlet of the Niagara gorge. Farther down the river, it is well shown as a superficial deposit of waterworn pebbles and sand at a height of

* This interpretation of the modern nature of the cañon in front of Foster's flats seems apparently to escape Mr. Taylor's observation, as he quotes Prof. Gilbert: "The shoals at Wintergreen flats (i. e. those at Foster's flats) and the Whirlpool Rapids are correlated with the epoch when the discharge of the upper lakes by way of the Trent and Mattawa Valleys left the Niagara River and Falls too small and weak for deep excavation" (p. 80 of Mr. Taylor's paper to be cited). As the modern cañon past Foster's flats is all that is being excavated by the full volume of the Niagara River, the extraordinary appeal for a cause of its smallness need not have been made to this evidently modern section had the rise of waters in the gorge been known, followed by the reëstablishment of the Gilbert Falls over the Medina sandstone, which falls in the form of the rapids are still *continuing.*

about 70 feet. These gravels are very thickly strewn upon the almost flat surface down to an altitude of about 50 feet above the lake, surmounted by low ridgelets. It extends as a zone eastward of the river and marks the gradual lowering of the lake, which at the mouth of the gorge is more strongly marked by the terrace (at 50 feet) and capping ridge of gravel (seen also at the site of the Church at Queenstown. It is seen at the St. Catherine's to the west. The Niagara Strand, east of the Irondequoit Bay, is represented by a sand terrace faintly separable from other delta deposits. West of Great Sodus Bay, it forms a strong terrace at about 40–50 feet above the lake, surmounted in places by a sand beach rising to 65–70 feet. At other points it is seen as the terrace plains of valleys.

The cause of the temporary rise of the waters of Lake Ontario is easy of explanation. From the excessive tilting of the earth's crust at the outlet of Lake Ontario, the water in the Niagara district rose (in so far as it affected the physics of the river) from a level 80 feet below that of the present day to about 75 feet higher than now. The subsequent withdrawal of the water was brought about by the St. Lawrence River cutting a deeper channel for itself, largely out of drift deposits, thus lowering the water of the lake to its present level. These conclusions are based upon the following evidence. The present channel of the St. Lawrence ordinarily varies from 60 to 80 feet, but there are deeper holes, one of which reaches a depth of 228 feet. In passing through the islands below the outlet of Lake Ontario, one is constantly observing fragments (sometimes of limestone rock) of the former bed of the river, now raised from 5 to 10 feet above its surface. But the first rocky barrier now crossed by the river is at the Galops Rapids, 75 miles below the outlet of the lake. The narrowest part of the river is here half a mile wide, with a depth, even on the rapids, of from 30 to 45 feet. Before the removal of the barrier by the river dissecting it, the water stood at from 100 to 140 feet above the present level. Many remaining points on the islands in the river rise to about a hundred feet or more. Upon the southern side of the St. Lawrence as at Cape Vincent, there is a series of terraces at 30, 40–45, 50–60, 80, and 90–100 feet within a mile and quarter of the shore. The northern shore rises to 100 feet, close to the river. The country at this height, or at slightly greater altitude, forms plains often miles in width, and extended across the channel of the St. Lawrence River, which is a groove excavated out of it. The material removed from the channel was largely drift, but not entirely. The plains characterizing the surface of the barrier to the Ontario basin are often in the form of terraces, bounded by abrupt steps (old shore lines or banks) rising to those of higher levels—notably at 90, 115, and 140 feet above

the lake. The succession of plains can be traced for a long distance down the St. Lawrence, so that one may conclude that there has been comparatively little warping or unequal deformation of the region, since the river began to deepen its channel. Thus it would seem that the dissected barrier had a height between 100 and 140 feet, and that the subsequent uplift of the region has been only about 25 feet more than at the mouth of the Niagara gorge. Thus the features of Lake Ontario confirm the hypothesis of the recent rising of the waters in the Niagara gorge, which has been adopted to interpret one of the important episodes in the history of Niagara River.

Explanation of the Narrows of the Gorge at the Whirlpool Rapids.

The most important feature in the history of the river that has remained unexplained is the narrowing of the cañon along the section of the Whirlpool Rapids. Mr. F. B. Taylor* has accounted for both the narrowness and the shallowness of the section somewhat as follows. He says that one of the principal hypotheses for explaining the section of the gorge at the Whirlpool Rapids is that "the whole gorge, excepting always the whirlpool basin, has been made by the modern or postglacial river Niagara, and that the magnitude of the gorge in the different sections is due to the variation of volume." He says that this seems to be the simpler of the hypotheses and proceeds *a priori* to support his proposition by a lengthy brochure entitled "Origin of the Gorge of the Whirlpool Rapids at Niagara." According to his supposition, the waters of the Huron basin, hitherto retained by an ice dam to the northeast, were now withdrawn from the Niagara discharge while the falls were passing the whirlpool section, thus reducing its volume to one-ninth the present amount. Here it should be noted that by actual measurement, the drainage is between $\frac{1}{3}$ and $\frac{1}{4}$ (at different periods of the season of measurement). Until there is a more perfect determination, these are the only figures that we have to go by. Not only has he reduced the discharge of the Niagara to half as great as indicated by ascertained data, but he neglects to take into account the evidence of the buried channel at this point, which in part still remains intact upon the sides of the chasm, and which the modern river has taken possession of. Such a depression is only characteristic of this section of the Whirlpool Rapids, for just at its foot the rocky walls are higher than those along the mid section. Mr. Taylor assumes that the preglacial gorge of the whirlpool ended abruptly, in an amphitheater, like modern cañons, and not by transition slopes (which everywhere mark the features of the preglacial erosion) from the buried

* Bull. Geol. Soc. Am., vol. xix, pp. 59–84, 1898.

valley above the cauldron. Indeed the sloping features are preserved in the extension of the whirlpool valley, where not remodified by the modern Niagara, showing that we have not far to go for evidence.

The diminution of the volume of the river would not explain the shallowness of the channel at the Whirlpool Rapids. We find to-day many small streams near the Niagara district which are excavating their cañons directly through the lower hard layers of the same strata as in the gorge, showing that the streams of insignificant volume are penetrating the rocks to the base-level of erosion as well as those of great magnitude. Consequently, Mr. Taylor's hypothesis does not satisfy the shallowness of the Whirlpool Rapids, which demands a reduction in the height of the falls, such as has been found to have obtained.

The other question which the hypothesis of the glacial dam was hoped to explain was the narrowness of the section of the Whirlpool Rapids. If the waters of the Huron basin had been completely diverted from the Niagara drainage at this time, the narrowing but not shallowing of the cañon might be partly explained. But of it there appears no evidence. From the preservation of the river banks outside of the narrows of the gorge, the width of the channel is seen to have been maintained at the full breadth and depth. This statement may be seen somewhat illustrated in fig. 1 (page 441), below which there is an explanatory note. The constriction applies to the gorge alone. This section differed materially from the country above and below it, as here the Niagara River came to occupy a shallow and small preglacial valley, which was filled by drift to the depth of forty or fifty feet, as seen in the banks of the deserted channel of the river beyond the edge of the chasm. The depth of the depression was greater in its center, and the river took possession of the deeper portion, and upon the removal of the drift, sunk within the narrow gorge. This is found to have been the case, for at the place where Mr. Taylor describes the pause of the falls, at the foot of the present Whirlpool Rapids, the surface rocky floor of the old valley at that point is 20 feet higher than in the deeper remains of the channel exposed above it; thus showing that there was a deeper medial channel subsequently developed into the narrow chasms. This shallow-buried valley began in Johnson's ridge, just above the railway bridges (see figs. 1 and 2), and extended to the whirlpool, whose cauldron is only the deeper extension of the same ancient channel. Accordingly it is readily seen that the length of the section of the Narrows and that of the preglacial depression coincide.

When the Falls had retreated as far as the whirlpool, and had removed the rocky barrier at its outlet, the buried channel

would have been quickly reëxcavated by the current easily removing the drift filling. With the channel being thus deepened so rapidly, in loose material, it would cause a concentration of the current within a narrow gorge, and materially augment the mechanical effects upon the floor of the cañon —thus deepening without broadening the chasm. Indeed, is not this feature of the contraction of the cañon perfectly developed at the outlet of the whirlpool, where the whole volume of drainage of all the upper lakes, by Niagara River, rushes, as out of a waste weir, through a channel only 400 feet wide, with an estimated depth of 50 feet? Thus there seems no reason to suppose that the volume of the river was, during this episode, reduced to one-fourth or one-fifth of the present amount,—as would have been the case with Mr. Taylor's hypothesis, especially as the work of the Falls would have been greatly diminished by the reduced descent of its waters (as already described on page 445).

A partial reduction of the volume of the water, at this time, was more than probable, but from another cause than that here discussed. In the "Duration of Niagara Falls,"* it was shown that the Johnson ridge caused the waters of the Erie basin to rise to the point of discharging a portion of the waters of the upper lakes into the Mississippi, by way of a new outlet near Chicago. But the falls dissected Johnson ridge before there was an extensive drainage of the Niagara waters to the Mississippi; whereupon there was a lowering of the upper lakes below the Chicago overflow. At this distant day, it is difficult to estimate the exact amount of such discharge which may have been greater than at first supposed. The terraces or shore-lines in the St. Clair outlet of Lake Huron, at an elevation of fifteen or twenty-five feet above the level of Lake Erie, apparently correspond with the level of the Erie waters, as they were being raised by the Johnson ridge before it was dissected by Niagara Falls. Thus the deserted shore-lines of the lakes support the evidence of the partial drainage, at this time, of the upper lakes into the Mississippi.

The physical conditions as now described account more fully for the narrows of the gorge than any previous explanation, as the cause of its shallowness seems to have been made clear. This solution of a condition previously overlooked may possibly be found entirely sufficient, and it has an advantage of being in full accord with mechanical forces which we see at work in Niagara to-day. The new discoveries in the history of Niagara River, which have here brought about a revision of the episodes, will somewhat alter the estimate of the age of the Falls from 32,000 years, but whatever figures result they will doubtless approach more nearly the true age of the Falls.

* Cited before.

ART. XLV.—*On an Apparatus for Measuring very High Pressures;* by A. DEFOREST PALMER, JR.

SOME time ago, while I was investigating the relation between the electrical resistance and the pressure of pure mercury, Prof. Barus remarked that the results might be used by exterpolation in the calculation of very high pressures, and suggested that I undertake the construction of an apparatus to utilize this principle and determine the limit of pressure obtainable with a tinned screw. After several disappointing preliminary trials the method described below was finally adopted and found to give very satisfactory results.

1.

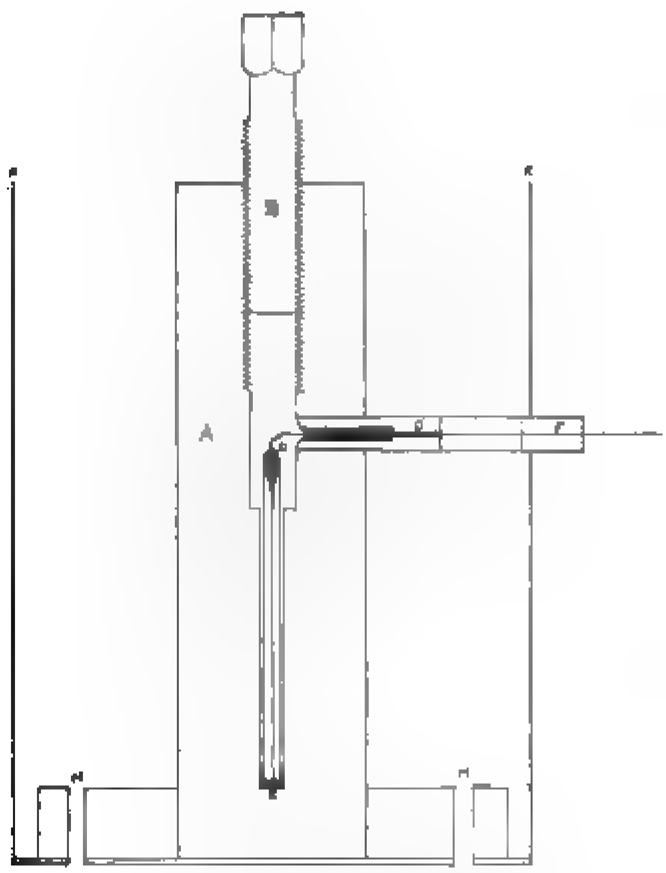
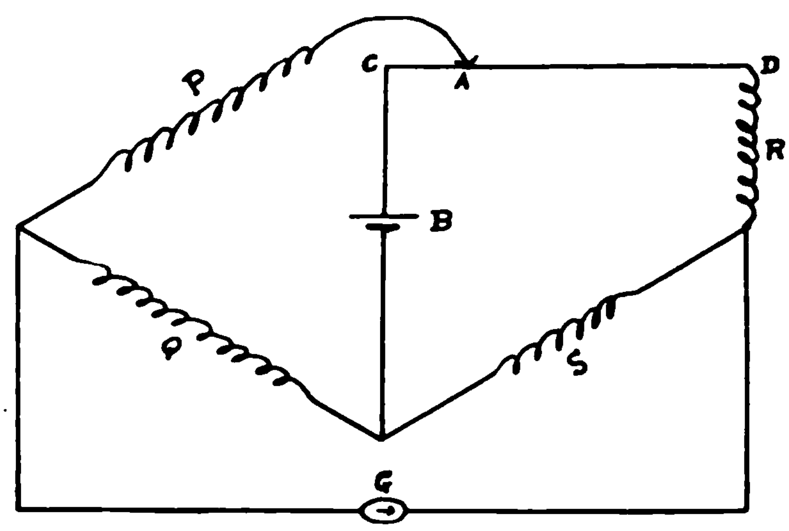


Figure 1 is a sectional diagram of the piezometer. A is a Bessemer steel cylinder, two inches in diameter and seven inches long, firmly keyed to a cast-iron collar having holes H H for anchor bolts. D is a capillary glass tube, about one-tenth millimeter in internal diameter and eight centimeters long, filled with pure mercury electrically connected with A by a globule of mercury E. A platinum electrode, sealed into the top of D, is soldered to a silk-covered copper wire that passes out of A through a marine glue plug in the tinned steel screw C and forms the upper connection with a Wheatstone's bridge.

The lower connection is made by a thick copper wire soldered to the bottom of A (not shown). The space between A and D is filled with heavy cylinder oil and the top of the cavity is closed by a tinned steel screw B, five-eighths of an inch in diameter and three inches long, actuated by a large tap wrench. The whole apparatus is surrounded by a tin can, K K, filled with melting ice to keep the temperature constantly at 0° C.

2.



The method used for measuring the changes in the electrical resistance of the mercury thread is illustrated diagramatically in fig. 2. B and G are the battery and galvanometer respectively, P Q equal resistances, R a known resistance, S the mercury thread, and C D a bridge wire. R is made nearly equal to the largest value of S and balance is produced by moving the contact A along the wire. Then if x_0 and x denote two positions of A corresponding to different values of S and β represents the resistance of unit length of the wire, we have for dS, the variation of S between the two settings,

$$dS = \beta(x_0 - x)$$

The sensitiveness and accuracy of the method depend largely on the sharpness of the contact A and the condition of the surface of the wire, but with reasonable care these conditions can be kept constant for a long time.

In a previous communication* I showed that, up to two thousand atmospheres, the relation between the electrical resistance and pressure of mercury is given by the linear equation

$$R = R_0(1 - aP)$$

where R_0 is the initial resistance, R the resistance at the pressure P, and a a constant coefficient. Transposing, we have

$$P = \frac{R_0 - R}{aR_0}$$

* This Journal, IV, iv, p. 1, 1897.

but with the connections described above

$$R_0 - R = \beta(x_0 - x)$$

hence

$$P = \frac{\beta}{a R_0}(x_0 - x)$$

and all the terms except P and x are constant so long as the temperature remains the same. During the present investigation the cylinder containing the mercury tube was surrounded by melting ice nearly an hour before the observations were begun in order that the temperature might become uniform, and after each increment of pressure sufficient time was allowed for the heat of compression to escape. The variation in the temperature of the wire was never more than two degrees and the change in β was negligible. The value of a at 0° C. is ·00003237, and R_0 was so chosen that $\beta/a R_0 = 4{\cdot}09$. Hence

$$P = 4{\cdot}09(x_0 - x)$$

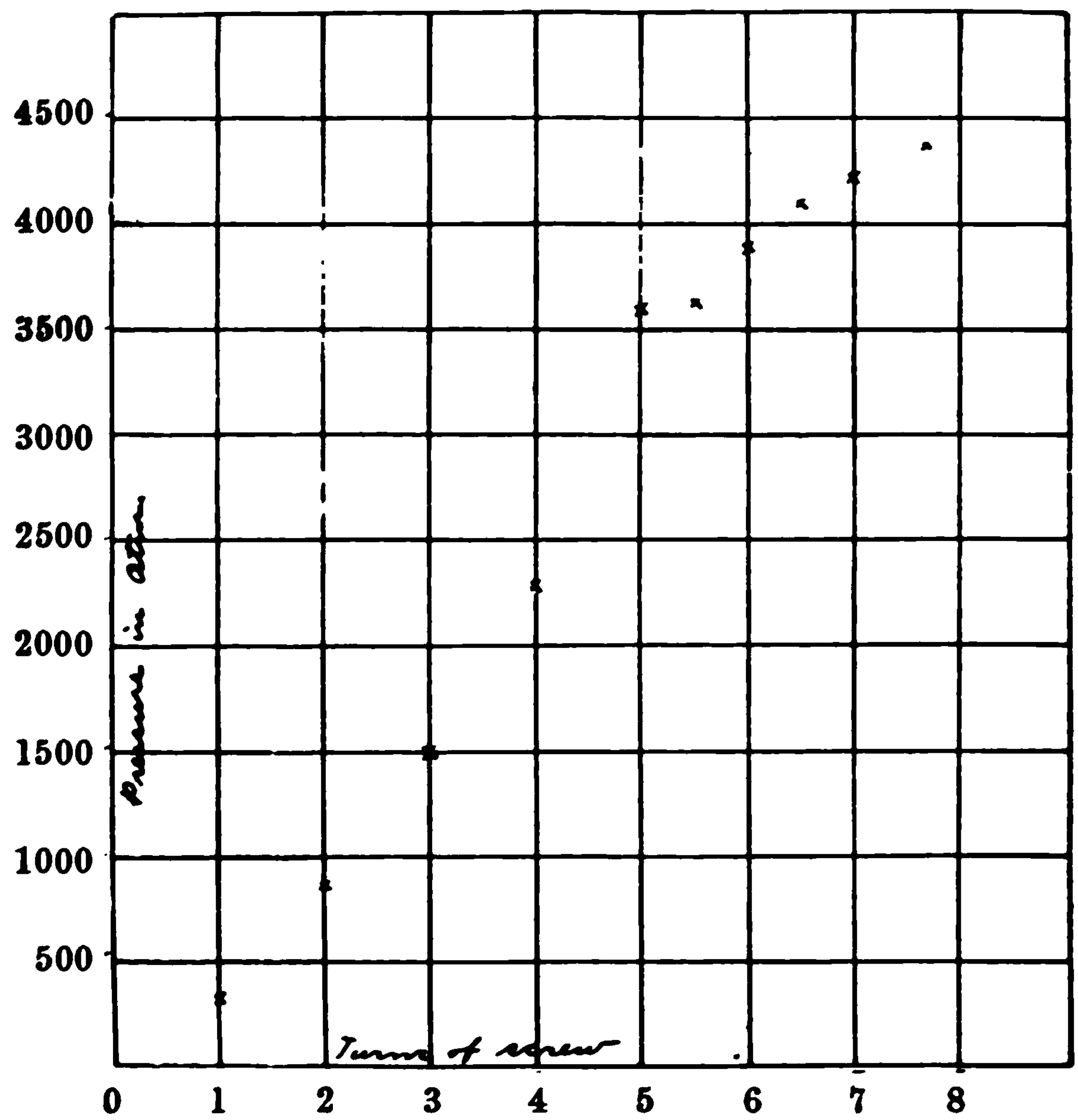
and, since a motion of the contact on the wire equal to two-tenths of a division was clearly indicated by the galvanometer, a change of pressure of one atmosphere could be easily detected.

The apparatus illustrated in fig. 1 was designed primarily to ascertain the limit of pressure attainable with a screw, but the same construction would serve as well for a pressure gauge in connection with any form of compressor by removing the screw B and inserting the connecting tube in its place. The method presents the following advantages. The apparatus is compact and, aside from the resistance boxes, etc., which are to be found in every well ordered laboratory, is inexpensive. It is free from leakage even at very high pressures. Observations can be quickly made and very easily reduced. The constants, except a, can be easily determined. With reasonable care the errors of measurement do not exceed one part in one thousand.

After a preliminary trial with a Bessemer steel screw, that broke when a pressure of 3554 atmospheres had been obtained, a bar of carefully annealed Stubb's steel was turned to fit the thread in A as accurately as possible and then very evenly tinned. Figure 3 exhibits the results of the final observations. The abscissas indicate the angular positions of the top of the screw, one division representing one whole turn, and the ordinates show the corresponding pressures, the scale being 500 atmospheres per division. After five complete turns, when the indicated pressure was 3600 atmospheres, the screw began to twist and it finally broke after 7·7 turns when the maximum

pressure was 4385 atmospheres. Below the yield point of the steel the volume decrement of the substance under compression is proportional to the angle through which the head of the screw is turned, and hence the first five points in this figure lie on a continuous curve without a point of inflection. At higher

3.



pressures the twist of the screw and the shear of its threads destroys the above proportionality and the remaining points lie much lower than they would if the screw had remained rigid up to the point of fracture. No method of accurately determining the extent of the distortion of the steel between the points of yield and rupture was at hand, but if, as is probable, the shear of the threads was small, the above results show that the twist was nearly two complete turns.

Brown University, Sept. 20, 1898.

ART. XLVI.—*The Application of Iodine in the Analysis of Alkalies and Acids;* by CLAUDE F. WALKER and DAVID H. M. GILLESPIE.

[Contributions from the Kent Chemical Laboratory of Yale University—LXXVI.]

IT is well known that when a free mineral acid is added to a neutral mixture of metallic iodate and iodide, the iodate is reduced and iodine is liberated according to the equation :

$$RIO_3 + 5RI + 3H_2SO_4 = 3I_2 + 3R_2SO_4 + 3H_2O.$$

This reaction is complete and non-reversible under the conditions of analysis, and it may therefore be applied to the estimation of amounts of iodate, iodide or mineral acid present in an unknown solution. A solution of iodate to be analyzed is mixed with an excess of iodide and mineral acid, the resulting free iodine estimated by directly titrating with sodium thiosulphate or arsenious acid, and one-sixth of the amount found taken as equivalent to the iodate originally present.* Similarly, a solution of iodide to be analyzed is mixed with an excess of iodate and mineral acid, the resulting free iodine estimated by directly titrating in alkaline solution with arsenious acid, and five-sixths of its amount taken as equivalent to the iodide originally present.† A solution of mineral acid to be analyzed is mixed with an excess of iodate and iodide, the resulting free iodine estimated by directly titrating with sodium thiosulphate, and its entire amount taken as equivalent to the amount of mineral acid originally present.‡ Gröger has applied the last mentioned method to the direct analysis of various mineral acids, and has obtained results manifestly better than those afforded by the use of vegetable indicators. Gröger has also indirectly analyzed solutions of alkali hydroxides and carbonates by adding the solution to be analyzed to a measured volume of mineral acid, previously standardized by the above method, and estimating the small excess of free mineral acid that finally remains by the same method. The only difficulty with the Gröger process lies in the fact that under the conditions present the end-point of the final reaction between iodine and sodium thiosulphate is somewhat obscured by a peculiar back-play of color due to a continuous slow liberation of iodine in the system.

When a solution of a metallic hydroxide is acted on by iodine at a temperature high enough to decompose the small

* Rammelsberg, Pogg. Ann., cxxxv, 493; Walker, this Journal, iv, 235.

† Gooch and Walker, this Journal, iii, 293.

‡ Kjeldahl, Zeitschr. für Analyt. Chem., xxii, 366; Furry, Am. Chem. Jour., vi, 341; Gröger, Zeitschr. für Angw. Chem., 1894, 52.

amounts of hypoiodites that might otherwise be present, the final action results in the formation of an exactly neutral mixture of iodate and iodide, according to the equation:

$$6ROH + 3I_2 = RIO_3 + 5RI + 3H_2O.$$

Phelps* has shown that in the case of barium hydroxide at least this reaction is regular and complete under the conditions of analysis, and is independent of the excess of iodine which remains in the neutral mixture unacted upon, and may be estimated by directly titrating with arsenious acid. Phelps not only applies this principle of action to the standardization of solutions of barium hydroxide by boiling with an excess of iodine in a trapped flask, but also bases thereon a differential method for determining carbon-dioxide, in which the liberated gas is run into a measured amount of barium hydroxide, the final excess of which is estimated by treating with iodine in the presence of the precipitated barium carbonate. The good result obtained by Phelps with barium hydroxide suggested that the attempt be made to analyze alkali hydroxides, and possibly carbonates, by a method, simpler than that devised by Gröger, based on the direct treatment of these compounds with iodine in hot solution. It also seemed possible to apply the differential method not only to carbon-dioxide but to any acid or other compound that will act definitely and completely with the metallic hydroxide employed, provided the soluble or insoluble product formed will not be attacked when heated in the presence of iodine. It was decided to modify the Phelps process, however, in order to obviate the necessity of handling large measured amounts of iodine in a flask trapped to prevent mechanical loss by heating. The flask was therefore dispensed with altogether, and the hydroxide solution to be analyzed was mixed with an approximately measured excess of iodine solution, in an Erlenmeyer beaker, the mouth of which was lightly closed with a little trap to prevent loss by spattering. The excess of iodine was then completely removed by boiling, and the cooled colorless solution remaining, which contained a neutral mixture of iodate and iodide, was acidified with a mineral acid and the liberated iodine titrated with sodium thiosulphate, the amount found being equivalent to the amount of hydroxide taken for analysis.

The present investigation was undertaken to study the limitations and possible applications in analysis of the reactions between iodine on the one hand, and barium hydroxide, potassium hydroxide and sodium carbonate on the other. It was soon found that the reaction in the case of sodium carbonate is entirely dependent on conditions of time, mass and tempera-

* This Journal, ii, 70.

ture, and cannot be pushed to completion except under conditions that make its application in analysis impossible. In the case of barium and potassium hydroxides both the original procedure of Phelps and the modification above described were employed. The modified method was found to be the more convenient and speedy of the two. The results obtained in both cases agreed with one another, but were invariably lower by a small nearly constant amount than those obtained by both the gravimetric and the Gröger processes. This error of the Phelps process and its modification is possibly due to the action of atmospheric carbon dioxide on the hydroxide solution during the short time it is exposed. While it will affect the value of the method as a means of accurately determining the absolute amount of hydroxide present in a given volume of solution, it cannot so affect the accuracy of any differential method founded on the original Phelps process or its modification. This is demonstrated by the work of Phelps in the case of carbon-dioxide, and by the present investigation in the case of hydrochloric and sulphuric acid. Analyses of these two acids were made by adding the solution to be analyzed to a measured volume of barium or potassium hydroxide, previously standardized by the modified Phelps method. The small excess of hydroxide remaining was then estimated by the same method, the results agreeing with those already obtained by both the gravimetric and the Gröger processes. It seems probable that other acids and compounds for which there is now no rapid iodometric method may be analyzed by a method similar to this, that has given good results with carbonic, hydrochloric and sulphuric acids.

Decinormal solutions of the alkali hydroxides were prepared, and kept with great care in trapped bottles, from which portions for analysis were measured by means of a self-feeding burette, which was also fitted with a trap. All vessels and water used were made as free as possible from carbon-dioxide, and the operations were conducted as rapidly as possible.

In the analyses by the Phelps method a carefully measured excess of decinormal iodine was drawn into a small ether wash-bottle, and the desired amount of alkali was rapidly run into it. The stopper, to which had been sealed a Will and Varrentrapp absorption bulb, was placed in the bottle and the bulb was charged with a 5 per cent solution of potassium iodide to catch any escaping vapors of iodine. The apparatus was placed over a low flame and the contents heated to boiling or slightly longer, and then cooled in a stream of water. The contents of the bulb and connecting tubes were then washed into the flask, and the excess of free iodine remaining was titrated with arsenious acid, in the presence of 5^{cm^3} of starch

emulsion. Blank analyses were made to insure against mechanical loss of iodine during boiling and to prevent any error on account of the presence of carbonate or other impurity in the solutions employed.

Some of the results obtained with barium hydroxide are given in Table I. The variation in different analyses of the same series is not large, and the results are independent of the amount taken for analysis and of the excess of iodine employed.

TABLE I.

Analyses of $\frac{N}{10}$ Barium Hydroxide Solution.

(By boiling in a trapped flask with an excess of iodine.)

	$Ba(OH)_2$ taken. cm^3.	Iodine taken. grm.	Iodine absorbed by $Ba(OH)_2$. grm.	$Ba(OH)_2$ found. grm.	Mean. grm.	Variation. grm.
(1)	10	0·13	0·1054	0·0712	0·0699	0·0013+
(2)	10	0·14	0·1028	0·0692	0·0699	0·0007−
(3)	20	0·23	0·2072	0·1399	0·1398	0·0001+
(4)	20	0·25	0·2074	0·1401	0·1398	0·0003+
(5)	40	0·44	0·4143	0·2798	0·2796	0·0002+
(6)	40	0·44	0·4148	0·2802	0·2796	0·0006+
(7)	40	0·48	0·4160	0·2809	0·2796	0·0013+
(8)	40	0·48	0·4126	0·2786	0·2796	0·0010−
(9)	40	0·51	0·4115	0·2779	0·2796	0·0017−
(10)	40	0·51	0·4136	0·2793	0·2796	0·0003−

The analyses of potassium hydroxide were made in the same way as were those of barium hydroxide, and gave quite similar results. They follow in Table II.

TABLE II.

Analyses of $\frac{N}{10}$ Potassium Hydroxide Solution.

(By boiling in a trapped flask with an excess of iodine.)

	KOH taken. cm^3.	Iodine taken. grm.	Iodine absorbed by KOH. grm.	KOH found grm.	Mean. grm.	Variation. grm.
(1)	10	0·20	0·1621	0·0716	0·0717	0·0001−
(2)	10	0·23	0·1613	0·0715	0·0717	0·0002−
(3)	15	0·30	0·2404	0·1063	0·1076	0·0013−
(4)	15	0·30	0·2429	0·1074	0·1076	0·0002−
(5)	15	0·34	0·2431	0·1075	0·1076	0·0001−
(6)	25	0·51	0·4089	0·1808	0·1792	0·0016+
(7)	25	0·51	0·4058	0·1794	0·1792	0·0002+

The analyses by the modification of the Phelps method were made by drawing into an Erlenmeyer beaker of convenient size an approximately measured excess of decinormal iodine, and rapidly running the desired amount of alkali into it. The

neck of the beaker was then closed by a little trap, made of one of the halves of a double end calcium chloride drying tube, to prevent appreciable loss by spattering. The beaker was then placed over a low flame, and the contents boiled until the last trace of the excess of iodine had volatilized from the solution and the trap. The volume was carefully regulated before and during the boiling, being kept as small as possible, usually amounting to about 100^{cm^3} at the start and 35^{cm^3} at the close. In the case of barium hydroxide care had to be taken to keep the dilution sufficient to prevent the separation of the crystalline barium iodate, which is soluble with difficulty. To steady the ebullition a little spiral of platinum was introduced into the beaker. After the boiling had ceased, the colorless solution, containing a neutral mixture of iodate and iodide, was cooled in running water, and treated with 10^{cm^3} of dilute (1 : 3) hydrochloric acid or (1 : 3) sulphuric acid. The liberated iodine was titrated directly with sodium thiosulphate, in the presence of 5^{cm^3} of starch emulsion. In the case of barium hydroxide, the iodine was liberated with dilute (1 : 3) hydrochloric acid to save the inconvenience of working in the presence of precipitated barium sulphate; with potassium hydroxide, however, dilute (1 : 3) sulphuric acid was employed. In view of a statement by Pickering* that titrations with sodium thiosulphate in the presence of acid involve an error, a series of blank analyses was made which showed conclusively that no such error exists under the conditions which obtain in the process under consideration. Care was also taken, as in a former case, to guard against the possible presence of carbonates or other impurities in the reagents employed.

In Table III are given the results of a series of analyses of barium hydroxide by the modified method just described. They agree fairly well with those of Table I.

The analyses of potassium hydroxide by the modified method are given in Table IV, and are found to agree well with those of Table II.

A gravimetric analysis of the barium hydroxide solution in which the barium was weighed as the sulphate, gave as a result 0·1411 grm. $Ba(OH)_2$ for each 20^{cm^3} taken. An analysis of the same solution by the Gröger process gave for the same volume 0·1420 grm. The result by the Phelps process, however, was 0·1398 grm., and by the modified process 0·1390 grm. That the difference of 2 mg. between the results by the gravimetric and the Gröger processes on one hand, and the Phelps process and its modification on the other, may be due to atmospheric carbon dioxide, has already been pointed out. A gravimetric

* Jour. of the Lond. Chem. Soc., xxxvii, 134.

analysis of the potassium hydroxide solution by evaporating and weighing as KCl gave 0·1111 grm. KOH for each 20^{cm^3} taken, agreeing with 0·1106 grm. obtained by the Gröger process. The analyses by the Phelps process and its modification for the same solution gave 0·1076 grm. and 0·1082 grm. respectively. These results are strikingly in accord with those obtained with barium hydroxide.

TABLE III.

Analyses of $\frac{N}{10}$ *Barium Hydroxide Solution.*

(By boiling with excess of iodine in an open beaker to decoloration, and acidifying the residue.)

	$Ba(OH)_2$ taken. cm^3.	Iodine taken. grm.	Iodine absorbed by $Ba(OH)_2$. grm.	$Ba(OH)_2$ found. grm.	Mean. grm.	Variation. grm.
(1)	10	0·13	0·1023	0·0691	0·0695	0·0004 −
(2)	10	0·16	0·1020	0·0689	0·0695	0 0006 −
(3)	15	0·18	0·1548	0·1046	0·1043	0·0003 +
(4)	15	0·20	0·1546	0·1045	0·1043	0·0002 +
(5)	20	0·23	0·2049	0·1384	0·1390	0·0006 −
(6)	20	0·25	0·2058	0·1390	0·1390	0·0000 ±
(7)	20	0·32	0·2065	0·1394	0·1390	0·0004 +
(8)	25	0·29	0·2567	0·1734	0·1738	0·0004 −
(9)	25	0·32	0·2562	0·1730	0·1738	0·0008 −
(10)	40	0·47	0·4120	0·2783	0·2780	0·0003 +
(11)	40	0·48	0·4119	0·2782	0·2780	0·0002 +
(12)	40	0·48	0·4152	0·2804	0·2780	0·0024 +
(13)	40	0·49	0·4109	0·2775	0·2780	0·0005 −

TABLE IV.

Analyses of $\frac{N}{10}$ *Potassium Hydroxide Solution.*

(By boiling with excess of iodine in an open beaker to decoloration, and acidifying the residue.)

	KOH taken. cm^3.	Iodine taken. grm.	Iodine. absorbed by KOH. grm.	$Ba(OH)_2$ found. grm.	Mean. grm.	Variation. grm.
(1)	10	0·20	0·1624	0·0718	0·0721	0·0003 −
(2)	10	0·23	0·1618	0·0715	0·0721	0·0006 −
(3)	10	0·25	0·1622	0·1717	0·0721	0·0004 −
(4)	15	0·30	0·2459	0·1087	0·1082	0·0005 +
(5)	15	0·34	0·2473	0·1093	0·1082	0·0011 +
(6)	15	0 38	0·2441	0·1079	0·1082	0·0003 −
(7)	20	0·41	0·3274	0·1447	0·1442	0·0005 +
(8)	20	0·46	0·3259	0·1441	0·1442	0·0001 −
(9)	20	0·51	0·3269	0·1445	0·1442	0·0003 +
(10)	25	0·51	0·4052	0·1791	0·1803	0·0012 −
(11)	25	0·57	0·4082	0·1805	0·1803	0·0002 +
(12)	25	0·63	0·4080	0·1804	0·1803	0·0001 +

In the application of the modification of the Phelps process to the indirect analysis of hydrochloric and sulphuric acids the procedure was essentially the same as that detailed for the analyses of barium and potassium hydroxides in Tables III and IV. The acid solution to be analyzed was drawn into an Erlenmeyer beaker, a measured excess of standardized alkali added, and the operation completed as described. It was found that barium hydroxide and potassium hydroxide may be applied with equal accuracy to the analysis of both hydrochloric and sulphuric acids. Some of the results obtained are given in Tables V, VI and VII.

TABLE V.

Analyses of $\frac{N}{10}$ Hydrochloric Acid Solution.

(By adding to excess of $\frac{N}{10}$ $Ba(OH)_2$, boiling with excess of iodine to decoloration, and acidifying the residue.)

	HCl taken. cm³.	$Ba(OH)_2$ taken. grm.	$Ba(OH)_2$ neutralized by HCl. grm.	HCl found. grm.	Mean. grm.	Variation. grm.
(1)	15	0·17	0·1128	0·0480	0·0476	0·0004 +
(2)	15	0·17	0·1118	0·0475	0·0476	0·0001 −
(3)	15	0·17	0·1112	0·0473	0·0476	0 0003 −
(4)	25	0·26	0·1860	0·0791	0·0794	0·0003 −
(5)	25	0·26	0·1866	0·0794	0·0794	0·0000 ±
(6)	35	0·34	0·2634	0·1120	0·1111	0·0009 +
(7)	35	0·34	0·2603	0·1107	0·1111	0·0004 −

TABLE VI.

Analyses of $\frac{N}{10}$ Hydrochloric Acid Solution.

(By adding to excess of $\frac{N}{10}$ KOH, boiling with excess of iodine to decoloration, and acidifying the residue.)

	HCl taken. cm³.	KOH taken. grm.	KOH neutralized by HCl. grm.	HCl found. grm.	Mean. grm.	Variation. grm.
(1)	20	0·14	0 0972	0·0633	0·0633	0·0000 ±
(2)	20	0·14	0·0975	0·0634	0 0633	0 0001 +
(3)	25	0·14	0·1222	0·0795	0·0791	0·0004 +
(4)	25	0·14	0·1207	0·0785	0·0791	0·0006 −

An analysis of the hydrochloric acid solution by the Gröger method, which was found to agree in every case with the gravimetric determination, gave for each 25cm³ 0·0801 grm. of HCl, agreeing with 0·0794 grm. and 0·0791 grm. obtained by the new method. An analysis of the sulphuric acid solution by the Gröger method gave for each 25cm³ 0·1241 grm. of H_2SO_4 agreeing with 0·1246 grm. obtained by the new method.

TABLE VII.

Analyses of $\frac{N}{10}$ Sulphuric Acid Solution.

(By adding to excess of $\frac{N}{10}$ $Ba(OH)_2$, boiling with excess of iodine to decoloration, and acidifying the residue.)

	H_2SO_4 taken. cm^3.	$Ba(OH)_2$ taken. grm.	$Ba(OH)_2$ neutralized by H_2SO_4. grm.	H_2SO_4 found. grm.	Mean. grm.	Variation. grm.
(1)	10	0·21	0 0884	0·0506	0·0498	0·0008+
(2)	10	0·21	·0·0880	0·0503	0·0498	0·0005+
(3)	15	0·30	0·1328	0·0754	0·0748	0·0006+
(4)	15	0·30	0·1313	0·0751	0·0748	0·0003+
(5)	25	0·43	0·2168	0·1239	0·1246	0·0007−
(6)	30	0·43	0·2600	0·1481	0·1495	0·0014−

This investigation shows that the reaction between iodine and hydroxides of the alkalies and alkaline earths in hot solution is regular and complete under analytical conditions, not being appreciably affected by the mass action of considerable excesses of iodine. The reaction is best applied in analysis by titrating the alkali with an excess of iodine, removing this excess by boiling, and estimating the iodine in the residue. While certain mechanical difficulties may affect the extreme accuracy of the process as a direct means for analyzing alkalies, the action is at all times regular and may be indirectly applied with fair accuracy to the analysis of various acids and possibly to other compounds. The reaction between iodine and alkali carbonates on the contrary is irregular and cannot be made the basis of any analytical process.

ART. XLVII.—*On the Associated Minerals of Rhodolite;* by W. E. HIDDEN and J. H. PRATT.

IN a recent paper on *rhodolite*, a new variety of garnet,* the authors gave a list of the associated minerals, and it is the purpose of this article to describe them more fully. All the minerals have been obtained from the gravel beds of Mason Branch, which empties into the Little Tennessee River about five and one-half miles below Franklin, the county seat of Macon County, North Carolina. These gravel beds have been mined quite extensively for rhodolite by means of hydraulic processes and the species herein described have been found wholly in the concentrates. When the minerals shall have been traced to their source, as they promise to be soon and mining *in situ* inaugurated here, this locality may be expected to become one of unusual interest to mineralogists and geologists.

Quartz.—Compact crystalline and granular quartz is abundant as rolled pebbles and rounded bowlders (rarely weighing above 20 kg.). Crystals are occasionally found but are of very ordinary character. Massive quartz enclosing rhodolite and iolite, often both in the same mass, are not uncommon.

Quartz pseudomorphs.—An important characteristic of the locality is the occurrence of quartz pseudomorphs in the form of isometric dodecahedrons, bearing upon their faces markings exactly like those seen upon garnets. These crystals, sometimes 1^{cm} diameter, are wholly perfect and are rarely irregularly grouped together. They are gray in color and apparently homogeneous, with the exception of numerous inclusions of minute red rutile and black menaccanite. Their density, determined upon a single typical specimen, was 3·203, which was low for garnet and high for quartz. When pulverized and treated with the heavy solution to separate out the rutile and menaccanite, the remaining material was found to be a mixture of colorless quartz and the rhodolite variety of garnet.

The manner of their original formation and what was the original dodecahedral mineral, offer peculiar problems, for the crystals are undoubtedly not ordinary pseudomorphs. They never show any projecting neck or rough broken surfaces such as would indicate a pre-existent cavity through which this material might have passed into a cavernous garnet. It is our intention to study sections of these crystals, to determine if possible, the relation of the quartz and garnet in them, whether there are parallel layers of these minerals or whether the optic

* This Journal, vol. v, p. 294, 1898.

axes of the quartz have a definite relation to the dodecahedral axes.

Corundum.—About one-seventh of the heavier concentrates are corundum crystals, in the form of hexagonal prisms terminated by the base, some of which are 1^{cm} in diameter. The surfaces and edges are usually rough, from natural corrosion while in place. The common color is gray, but pale blue, pink and amethystine shades are often found. Ruby-colored crystals also occur and some of them are nearly transparent. A few of the amethystine crystals would furnish fairly good gems. No corundum has, as yet, been found *in situ* in the valley and no matrix is to be seen left upon the crystals.

Spinel Group.—This group constitutes about five per cent of the concentrates and seems to include the three species, pleonaste, gahnite and chromite.

The *gahnite* has a density of 4·24–4·40 and has been analyzed by Dr. Charles Baskerville* with the following results:

		Ratio.		
Al_2O_3	61·09	·599		= 1·13
FeO	7·78	·108		
ZnO	27·44	·339	·530	= 1·
MgO	3·30	·083		
	99·61			

From the above analysis, the mineral is shown to be the kreittonite or zinc-iron variety of gahnite. The ratio of ZnO : FeO : MgO is close to 12 : 4 : 3, which would give for the formula of this gahnite (12Zn . 4Fe . 3Mg)O . Al_2O_3.

The mineral has a clean glassy fracture like that of some dark obsidians and is deep bottle-green by transmitted light. The octahedron alone and in combination with the rhombic dodecahedron were the only forms observed on the crystals. The faces are never smooth but have an irregular and rounded appearance very similar to the so-called "fused quartz." Smooth fragmentary masses are most common, varying in size from 3^{mm} to $1·5^{cm}$ in diameter and are very free from inclusions.

Of the *chromite* only a few small pieces were found, but these would seem to indicate that there is now or has been a rock of the peridotite character in this valley from which this chromite originated. No basic magnesia rocks are known to be exposed in this locality.

The specimens are kidney-form and about 1^{cm} in diameter. They have a very brilliant luster upon a fractured surface and are of a pitchy-black color. A specific gravity determination gave approximately 4·7.

* University of North Carolina.

Bronzite.—This mineral is rare but occurs as highly etched fragments which are pale yellow to deep brown in color and are perfectly transparent, a very exceptional quality of bronzite. A beautiful silky sheen sometimes shines out from it when held at the proper angle similar to that seen in the chrysoberyl cat's-eye. The largest piece weighed 1½ grams and furnished a beautiful gem, much resembling the brown tourmalines from Ceylon. With the hand dichroscope it exhibited beautiful brown and green colors.

The specific gravity of the mineral is 3·43 and its fusibility 5½ to 6.

A little bronzite has been found associated with a very dark green massive amphibolite occurring as erratic bowlders.

Iolite.—The iolite has been found abundantly embedded in small bowlders of a granular quartz. The rock has very much the appearance of a conglomerate with quartz as the cementing material, and it could be well called an iolite pegmatite.

The surface iolite has undergone alteration and left the quartz cavernous and cellular, and only by breaking these bowlders open can the purer white iolite be obtained. This, however, is not entirely free from alteration, for it shows a thin silky to micaceous coating and shows internally minute scales of mica (biotite?), which lie parallel to the basal plane. The rhodolite garnet is the only mineral as yet identified as occurring directly with the iolite, but staurolite, cyanite, pale green apatite and rutile seem to be present. The minute inclusions of mica give rise to a beautiful golden sheen when the iolite is viewed in the direction of the vertical axis in reflected light, thus promising a new chatoyant gem.

No crystal planes have been observed, the mineral being columnar and varying from 3 to 25^{mm} in diameter and length. The color is pale yellow to greenish yellow. The mineral is nearly transparent but is wholly devoid of dichroism, so eminent a characteristic of the species. The analysis by Baskerville identifies this mineral as iolite.

The result of the analysis is as follows:

Specific gravity = 2·54

		Ratio.		
SiO_2	47·60	·793		= 9·00
Al_2O_3	36·20	·354		= 4·01
FeO	2·13	·015	·283	= 3·21
MgO	10·73	·268		
CaO	trace			
H_2O	3·14	·174		= 1·98
	99·80			

In the above analysis the ratios only approximate to the generally accepted formula, $H_2O . 4(Mg . Fe)O . 4Al_2O_3 . 10SiO_2$, and it is undoubtedly due to a slight admixture of some hydrated iolite with the material analyzed.

Cyanite, tremolite, fibrolite (?), hornblende, rutile and menaccanite occur, but of a too common order to merit any extended mention in this paper.

Staurolite.—This mineral has a rich garnet red color and is perfectly transparent; being apparently free from its customary inclusions. Its specific gravity is 3·80.

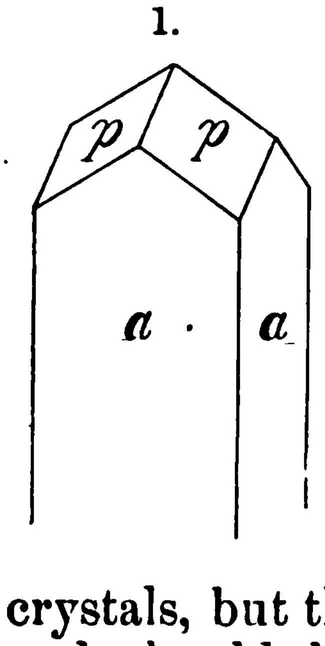
Only small fragments and rounded masses of the staurolite have been found and these were often mistaken by the miners for the pyrope garnet.

Monazite and Zircon.—These two species occur abundantly as minute crystals and grains in the finer and heavier concentrates. They rarely exhibit well-defined crystalline forms but are usually perfectly transparent and very brilliant.

A few rough crystals of monazite were found that were decidedly *green* in color and were from 2–6^{mm} thick in the direction of the *b* axis. This green color would seem to indicate the isomorphous replacement of ThO_2 by UO_2 similar to the occurrence in the green xenotime of Brindletown, N. C.*

Cyrtolite.—Genth† has mentioned the occurrence in this valley of "peculiar dark brown crystals from 1–3^{mm} in size which may be zircon." What are probably the same kind of crystals have been found in the concentrates with the rhodolite, but only two of these were saved. The exterior of the crystals is black or very dark brown, while the interior of one is a yellowish brown. The specific gravity is 3·71.

1.



One of the crystals measured 6^{mm} in the direction of the *c* axis. Orienting the crystals according to zircon, the only forms observed were the prism of the second order *a*, 100 and the unit pyramid of the first order *p*, 111, which were identified by means of the contact goniometer, giving $p \wedge p' = 56° 30'$, while for zircon $p \wedge p' = 56° 40' 26''$. The crystals were smooth and developed as represented in fig. 1, neither of them being doubly terminated.

No analysis has as yet been made of these crystals, but they are undoubtedly hydrated alteration products and should be classified with the so-called malacon and cyrtolite group.

Gold.—A small sample of slightly impure gold was finally saved, after much labor of rewashing the concentrates and

* L. G. Eakins, this Journal, June, 1892.

† Bulletin U. S. Geol. Survey, No. 74, 1891, p. 49.

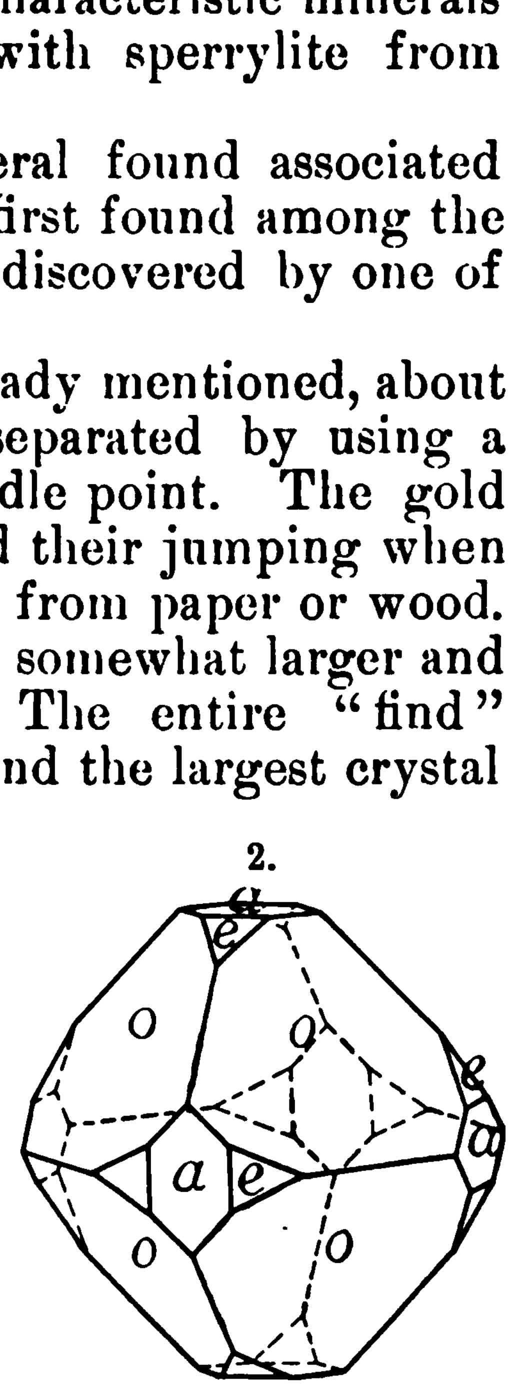
panning them down to a practical minimum. This sample weighed 1·75 grams and represented the gold from many hundred cubic yards of gravel and thus proved its rarity in this locality.

This gold was assayed and the resulting button weighed 1·2757 grams. Its specific gravity was 17·88. The pure gold weighed after separation from the alloyed silver 1·1583 grams, showing the Mason's Branch gold to be 90·77 per cent "fine." This is interesting because the neighboring Caler Fork (distant two miles N. E.) gold* had a "fineness" of 90·10 per cent and thus a constancy is shown for the region generally. In the concentrates containing this gold, over 300 crystals of sperrylite were found and also all the other characteristic minerals mentioned by one of us as occurring with sperrylite from Caler Fork.*

Sperrylite.—The most important mineral found associated with the rhodolite is sperrylite. It was first found among the gold particles in a similar manner to that discovered by one of us on Caler Fork, in Macon County.*

From the 1¾ grams of impure gold already mentioned, about 300 crystals of sperrylite were finally separated by using a strong pocket lens and a moistened needle point. The gold sands were spread out upon glass to avoid their jumping when touched, as the particles are prone to do from paper or wood. The crystals have sharper edges and are somewhat larger and brighter than those from Caler Fork. The entire "find" did not exceed one milligram in weight and the largest crystal was 0·4^{mm} in diameter. The octahedron apparently predominates, though many of the crystals show an equal development of the cube and octahedron. On a very few of the crystals, there was a slight development of the pentagonal dodecahedron *e*, 210, represented by fig. 2, which was prepared by G. H. Edwards of the Sheffield Scientific School, who identified the faces by the following measurements:

2.



		Measured.	Calculated.
$o \wedge a$,	$111 \wedge 010$	54° 56′	54° 44′
$o \wedge o$,	$111 \wedge 1\bar{1}1$	70 48	70 32
$a \wedge e$,	$100 \wedge 210$	26 28	26 34

These results prove that these sperrylite crystals are isometric and pyritohedral and, therefore, are like the original sperrylite from the Algoma district, near Sudbury, Canada.

* This Journal, vol. vi, p. 381, 1898.

One-half mile due north of the rhodolite placer mine, near the summit of Mason Mountain, a ledge of rock is exposed, which is composed almost entirely of impure rhodolite and biotite, with a very considerable quantity of the iron sulphides disseminated through them. Sperrylite has been obtained by panning the sands naturally concentrated in the crevices and cavities weathered in the ledge, which would seem to indicate that this ledge is one of the original sources, if not *the* source, of the sperrylite found in the valley below.

In conclusion the authors wish to express their thanks to Prof. S. L. Penfield of the Sheffield Scientific School for his kindness in making many tests to positively identify the minerals herein described.

September, 1898.

Art. XLVIII.—*A Revision of the Moraines of Minnesota;* by J. E. Todd.

For our knowledge of glacial deposits of Minnesota, so far as has been published, we are indebted almost entirely to the excellent work of Mr. Warren Upham. Even where others have been employed in detailed work, he has correlated and interpreted the data. The following criticism of his conclusions is done with the most friendly feelings and prompted only by the love of truth. It has seemed advisable that the present view should be presented, that the scientific world might judge for themselves regarding the comparative correctness of the two views.

When called to share in the work of unraveling the Pleistocene geology of Minnesota four years since, the impressions of the writer were mainly in harmony with those of Mr. Upham. It has been his province to examine the northwestern counties of the State, and it should be remembered that the interpretation offered below is based mainly upon observations in the western half of the State. The work in Hubbard and Beltrami Counties soon presented the case in a different light. From a comparison of our map (p. 471, scale, 70 miles to the inch) with those referred to below, the salient differences of interpretation will appear clearly.

It will be seen that, according to Mr. Upham's view, all of the moraines crossing Minnesota and Dakota have been formed by an ice sheet moving southward. Time not permitting us to follow the growth of his views, we take their ripe expression as given in the 22d annual report of the Minnesota Geological Survey. This southerly motion persists without much reference to topography. The stages marked by the separate moraine as recognized by Mr. Upham are as follows:*

1. The Altamont, extending into Southern Dakota and to Des Moines, Ia.
2. Gary Moraine, extending to Mineral Ridge, near Boone, Iowa.
3. Antelope Moraine, extending to Pilot Mound in Hancock County, Ia.
4. Kiester Moraine, extending into Freeborn and Faribault Counties.
5. Elysian Moraine, extending into southern LeSeur County.
6. Waconia Moraine, extending to Waconia, Carver County, Minn.

* Ice Age in North America, pp. 545–. The Glacial Lake Agassiz, Mon. xxv, U. S. G. S., pp. 141–.

7. Dover Moraine, extending into southern Kandiyohi County.

8. Bergus Falls Moraine, which passes Fergus Falls and extends into Morrison County.

9. Leaf Hills Moraine, forming with the preceding the main portion of the Leaf Hills and extending into northern Todd and Morrison Counties, thence east-northeast nearly to Grand Marais on the north shore of Lake Superior.

10. The Itasca Moraine which surrounds Lake Itasca, runs south of Leach and Pokegoma Lakes nearly to Grand Portage on Lake Superior.

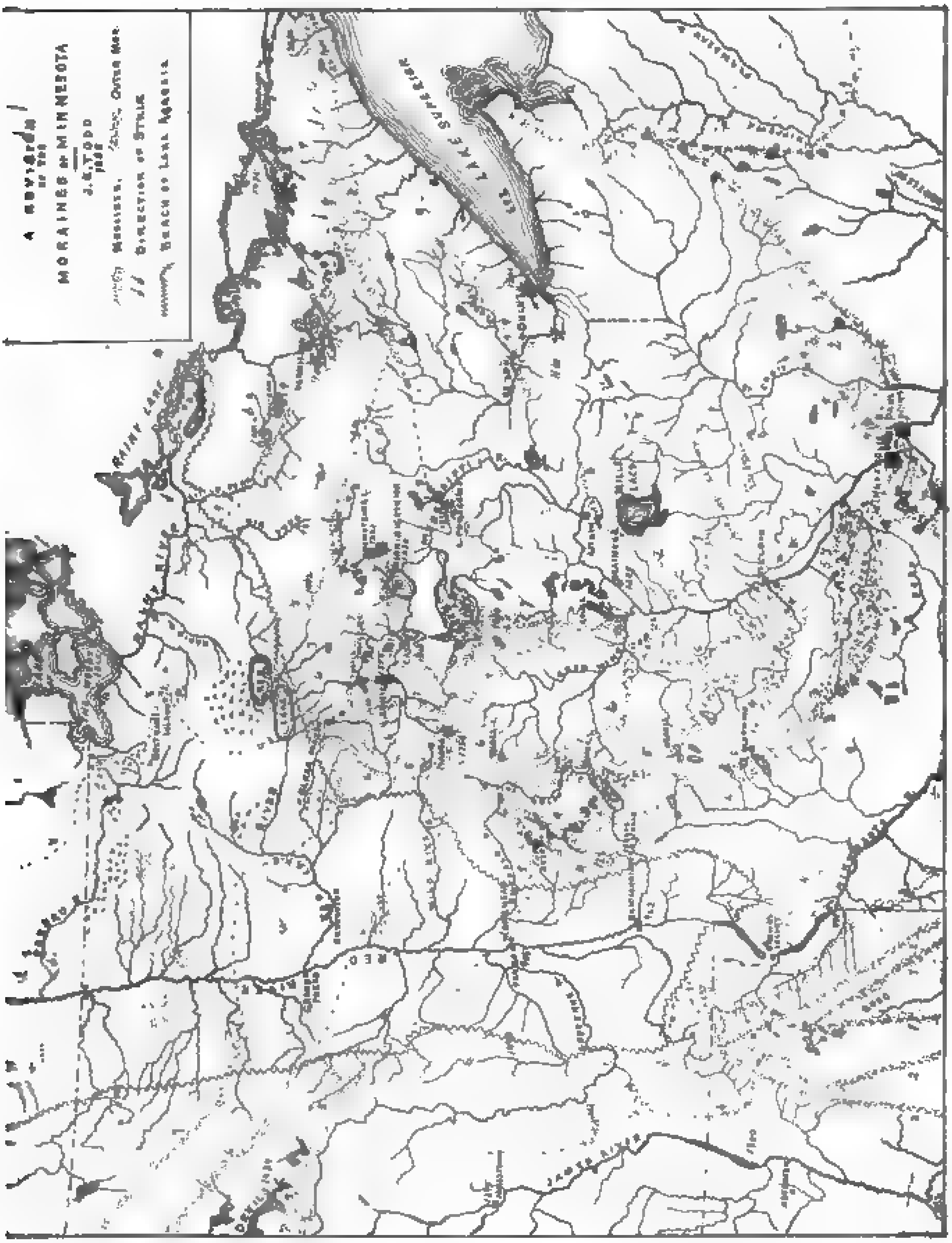
11. Mesabi Moraine, which separates the two portions of Red Lake, lies along the divides of Cass and Winnibigoshish Lakes, thence forms the so-called Mesabi range and strikes Lake Superior at Pigeon Point.

12. Vermillion Moraine, which lies south of Net, Pelican and Vermillion Lakes.

The following objections present themselves to this interpretation:

First, it assumes that latitude had more to do with the movement of the ice sheet than altitude. This is contrary to what we learn either from the movements of existing ice sheets in Greenland and Alaska, or in the case of the Dakota and Michigan lobes of the Pleistocene ice. It is true almost without exception that in the zone of ablation the ice seeks the lowest levels with a persistence nearly equal to that of water. There can be no question that the ice, at least in its later stages, lay in the zone of ablation rather than in the zone of accumulation. The scheme presented above shows little or none of this rule. The ice is represented as vacating the Lake Superior basin and the Red River valley much sooner than it did the elevated region around Itasca. The abrupt rise along the northwest shore of Lake Superior of more than a thousand feet seems not to have exerted any perceptible influence on the direction of the Leaf Hills and Itasca Moraines. In the Mesabi Moraine southeast of Red Lake we find it rising from about 1200 feet at Red Lake to more than 1400 feet on a divide without apparently responding to the influence of the surface at all. In fact, instead of running westward down the slope, as would be analogous to known cases, Mr. Upham represents it as turning eastward so as to form a reëntrant angle.

Second, it does not represent the ice as retiring in the proper direction to explain the formation of the early stages of Lake Superior, when it formed beaches 500 feet above the present lake around its western end and discharged through the St. Croix River. Nor is it in harmony with the subsequent or contemporaneous retreat of the edge of the ice dur-



ing the different stages of Lake Warren. We might add also that it disagrees with the existence of seven or eight moraines as found by Professor F. H. King in the valley of the Upper Flambeaux River, as published in Vol. IV, Geology of Wisconsin. This discrepancy seems to me surprising when we remem-

ber that Mr. Upham strongly argues for the glacial character of these early lakes.

Third, it does not correspond with the directions of striæ. This is particularly true of the striæ at Duluth and Carlton. As reported in Mr. Upham's paper in the 22d annual report of Geol. Survey of Minnesota, the striæ are represented as being prevalently parallel with the axis of Lake Superior or extending west-southwest. Indeed, some are directed north of west. On the same map a number north of the Mesabi range are represented as extending southwest, indicating a decidedly westward movement of the ice in the region in the northern part of Lake County and also about Rainy Lake. Still more decisive are the striæ found along the upper course of Big Fork in southern Itasca County, where the prevalent movement seems to have been westward. Unfortunately, we have not the evidence of striæ to assist us in the western half of the State.

Fourth, this view does not harmonize with the motion of the ice as indicated by bowlders. The White Earth Reservation west of the great divide abounds in limestone bowlders. They are also abundant about Black Duck Lake and Turtle River Lake in Beltrami County, but are rare in the whole of the Mississippi River basin. This is difficult to account for, provided the ice moved for a long time southward from the Red Lake valley into the Mississippi basin.

Mr. J. E. Spurr, in his report of 1893 (Minn. Geol. Survey), calls attention to the fact that the Mesabi range contains bowlders from the north entirely, while the moraine next south "is characterized by the constant presence of large bowlders of the coarse orthosyte and other rocks which are found chiefly from the Keweenawan province and so must have come in a southwesterly direction." He also calls attention to the fact that the area between the southern moraine, which is identified by Mr. Upham with Leaf Hills and the Mesabi Range, is covered with drift similar to that of the moraine mentioned.

Fifth, it does not agree with later observations of morainic areas. As these will be more fully given in a subsequent section, we will simply indicate some of the more significant points here.

In the northern part of Hubbard County and southern part of Beltrami, two moraines were found extending in approximately parallel curves, convex toward the west, one of them forming a reëntrant angle south of Leach Lake.

The moraine about Itasca seems quite as closely connected with the morainic areas southwest as toward the east, and from the topography it seems probable that the ice lingered toward

the south longer because it is at a lower level. About Detroit City and White Earth Agency the drainage is distinctly eastward through the western moraine and down the valley southward. This is indicated by the character of the deposits, which are of a sandy nature and lying in terraces.

Curving westward from the strongly developed north and south moraines upon the divide between the Mississippi and Red River basins, is a short spur south of the Wild Rice River in Norman County and ending abruptly along the Upper Herman beach. A similar westward branch of the moraine turns westward between Hill and Lost Rivers in eastern Polk County. This ends abruptly at a beach marking a lower stage of Lake Agassiz. This is on Section 31, T. 150–40. Moreover, a broad channel with terraces extends from a gap in this moraine southwestward to the beach, indicating a discharge of a stream apparently from the southern edge of the lobe occupying the Red Lake area into Lake Agassiz. The course of Clearwater and Red Lake Rivers, together with a certain subdued unevenness of a belt extending northwest from this point, seems to indicate the location of the edge of the ice in Lake Agassiz during the formation of the moraine.

Having expressed thus definitely our dissatisfaction with the former interpretation, we proceed to outline one that seems to avoid these difficulties.

During the occupation of this region by the ice sheet, we conceive that it moved mainly in two great lobes; one coming from the northeast through the valley of Lake Superior, the other from the northeast and north in the valley of Red Lake and Red River. This latter divided so as to pass down both the James River in Dakota and the Minnesota River. During the Wisconsin stage the two principal lobes mentioned were probably confluent over the whole of Minnesota, except the southeast corner. This was indicated by Mr. Upham in the 9th annual report of the Minnesota Survey, and was followed with some modification by Professor Chamberlain in the 3d annual report of the United States Geological Survey. The main modification was that he conceived the lobes to be more separated by the divide along the Mesabi Range. As the ice receded and stood at intervals to form the different moraines, there was the growth of a long interlobular moraine, first northwest from Minneapolis to the Leaf Hills, thence north and later northeast, following approximately the present divide between the two main valleys, so as to finally connect with the Mesabi moraine. This would evidently derive its material from the western side of the Lake Superior lobe and the eastern side of the western lobe. As different stages were reached in the recession, this interlobular portion would

lengthen along the intersection of the lobes toward the north and later toward the northeast.

As the lobes became more attenuated and separated, the moraines, though still having an acute angle ending in a more or less tapering ridge, would become more divergent toward the south. During the formations of successive moraines, this acute angle would be the scene of copious drainage from the adjacent sides of the two lobes. This drainage would be mostly toward the south. One result of this may be seen in the location of streams, as in the case of the upper portion of Otter Tail River and the Pelican, Buffalo and Wild Rice Rivers. There would also be abundant accumulations of sand and gravel in the form of terraces and plains between the two members of the interlobular moraine. But the matter will be more fully understood after a tracing of the moraines.

The First, or Altamont, moraine was evidently formed when the ice was near its maximum stage in the Wisconsin epoch and probably when the Lake Superior lobe was confluent with the western lobe and its branch occupying the Minnesota valley; so that the moraine was formed extending as far south as Des Moines and thence northwest, passing a little east of Minneapolis and so on northeast quite directly toward Keweenaw Point.

During the formation of the Second, or Gary, moraine, the two sheets of ice began to show their separate character and probably began to accumulate to an indefinite extent heavy deposits of drift extending west and northwest from Minneapolis, possibly uncovered, at least in its later stage, as far west as Wright and Meeker Counties. From the appearance of blue till overlying the red in eastern Minnesota we may infer that some time previous to this stage the western lobe extended farther east. Whether this was before or subsequent to the main accumulations of drift northwest of Minneapolis is undetermined.

During the formation of the Third, or Antelope, moraine, while we may suppose the Lake Superior lobe receded but little, or may, possibly, have advanced somewhat from its closer connection with the fountain of ice northeast. The slender lobe occupying the Minnesota valley receded to a point near the southern line of Minnesota upon the south, and on the southwest had withdrawn from the eastern slope of the Coteau des Prairies. Upon the east it seems to have receded into Meeker and Kandiyohi and Pope Counties. The prominent morainic accumulations along that line may have been partly accumulated at a previous stage. The valley of the north branch of Crow River lay between the Minnesota and Lake Superior lobe at this time.

The Fourth moraine, namely that crossing Lake Traverse and lying along the east side of Big Stone Lake and Minnesota River and connecting with the main moraine upon the east in Pope County, or Mr. Upham's 7th moraine, is quite feebly developed, which corresponds to the reduced strength of the western ice lobe. This rapid recession from the west and south seems a natural consequence of its greater exposure to the warm southwestern winds.

We are unable to follow Mr. Upham in his recognition of the Kiester, Elysian and Waconia moraines, for they seem to us based upon reëntrant angles of the Third moraine. It is probable that during the formation of the Fourth moraine the separation of the ice lobes had extended as far north as the Leaf Hills in the southern part of Otter Tail County. It is impossible, from our present knowledge of the region, to satisfactorily analyze the very complicated tangle of morainic ridges which are included under the general head of Leaf Hills.

In eastern Clay County a spur of the western branch of the interlobular moraine indicates a Fifth moraine, which seems to have been overlooked by Mr. Upham. The junction of this moraine with the highest beach of Lake Agassiz is shown upon the map of Clay County in the second volume of the Geological Survey of Minnesota. At that time, if we interpret rightly, the reëntrant angle of the moraine extended probably as far north as the head waters of the Wild Rice; and considerable drainage from the western lobe escaped down the valley past Detroit by the upper course of Pelican River. Probably at the same time, although not certainly, the edge of the Lake Superior lobe was forming the moraine which passes through range 39 along the east side of Otter Tail River and Otter Tail Lake past Osakis Lake and along Sauk River. It seems not improbable that the morainic portion in eastern Sherburn County belongs to this stage, and even as late as this the ice may not have withdrawn to any extent from the St. Croix River on the east.

South of the Wild Rice another prominent moraine disappears in the bed of Lake Agassiz, which we will call the Sixth. At that time, if we comprehend rightly, the lobes had been separated along the line curving quite sharply eastward in southern Beltrami County. The two members of the moraine pass on opposite sides of the lower Wild Rice Lake and become united and gradually disappear at a point on the divide north of Lake Bemidji. To this stage we would refer, with considerable confidence, the morainic accumulations about Lake Itasca, which, as we have before suggested, we consider a reëntrant angle pointing eastward, owing its existence to the elevated character of that region. The region about Itasca in

places reaches an altitude of 1750 feet, while upon the divide north of Lake Bemidji it is very little over 1400. This difference in level may account for the remarkable extension of the Lake Superior lobe toward the northwest. This we connect with the moraine running east of Shell Lake in Beeker County and more distinctly developed south of Pine Lake and in northern Todd County. In the northeastern corner of that county it changes from an easterly direction to one due south, and includes the morainic accumulations west and east of St. Cloud. Its further development we do not venture to indicate.

The western lobe seems to have continually receded more rapidly than the eastern, and we find again the short portion of a moraine—the Seventh—joining the lower Herman or Norcross Beach of Lake Agassiz in township 150–40. From that point it runs eastward south of Red Lake, probably connecting with a moraine along Big Fork in its eastern course north of Bow String Lake, though it has not been clearly traced. Corresponding in time to this is a moraine found running between Turtle Lake and Lake Bemidji, thence curving southwest, south to southeast through eastern Hubbard County and western Cass County to Gull Lake near Brainard.

There is lying approximately parellel with this a moraine passing north of Cass Lake, crossing the Mississippi east of Lake Bemidji, thence curving toward the south and southeast, forming a prominent reëntrant angle on the south side of Leach Lake. Thence it runs west of south and joins the moraine just mentioned near Gull Lake. Both of these united are believed to correlate with the morainic ridges of interlobular character which lie in Crow Wing and Morrison Counties, the elongated portion trending northeast in northern Kennebeck County, also the ridges in the southern part of the same county and on the south line of Pine County. The distinctly double character of this moraine at its northwestern extension seems to be a result of the unusual elongation of the lobe in that direction. It may be stated also that this seventh moraine shows an indistinct double character.

During the formation of the Eighth, or Mesabi, moraine, we conceive that the two ice lobes had become separated to an indefinite extent, at least beyond the borders of Minnesota, and were forming between them the Mesabi moraine. If we are correct in this supposition, the moraine before mentioned along the Big Fork must have been extended south-eastward so as to connect with the Mesabi. At this stage for some reason the push of the northern ice lobe seemed to have been more strongly southward toward the east; while the southern ice lobe, as in the preceding stage, still pushed strongly northwest. A reason for this may be found in the much steeper slope on

the south side of the divide along Lake Superior. To this stage we refer the morainic ridge separating the two portions of Red Lake, the prominent points of the so-called Beltrami Island south of the Lake of the Woods, the outer portion of the Mesabi range. The course of the moraine around the Lake Superior lobe we do not venture to point out, except to suggest that it may include the moraine south of Lake Pokegama and probably some portions in western Aitkin and Mille Lacs Counties, together with some portions of the singularly elongated ridges trending northeast, portions of which we have referred to the preceding stage. Our conception is that at this time the Superior lobe had become more attenuated and was traversed by channels draining southwest which first tended to form osars; and these eventually grew into interlobular moraines somewhat as McGee has found in eastern Iowa.

During the formation of the Ninth, or Vermillion, moraine the ice lobes had retreated some distance from each other, and the northern was forming the Vermillion moraine as has been traced by Mr. Upham, while the Lake Superior lobe was forming the moraine south of Cloquet River; and probably the northeastern portion of the northeast ridge in Carlton County may have been formed at this time.

In this way we venture to attempt a solution of the unusually perplexing problem of the morainic accumulations of the northwest. The first stage of Lake Superior, when its highest beach was formed and its outlet was by the Bois Brule into the St. Croix River, followed soon after the vacation of this ninth moraine.

Before closing, we may add a few suggestions as to the possible correspondence of the Minnesota moraines on the south side of Lake Agassiz with those traced by Mr. Upham and published upon his map in his work upon Lake Agassiz. We have little difficulty in correlating the first three moraines as has been done in the third annual report of the U. S. Geological Survey. The fourth seems to correspond with the fourth as published in Bulletin 144, U. S. Geological Survey. This may have had upon its western member a double development because of the more rapid retreat of the ice from that direction, which would explain the scattered development of the moraine along the Cheyenne River in North Dakota. The fifth seems to correspond in position with one indicated by Mr. Upham as following up the east side of the Cheyenne River and more distinctly developed south of Devil's Lake. The sixth probably corresponds to the Tiger Hills or the Arrow Hills moraine, and the seventh to the moraine crossing the Manitoba and Northwestern R.R. near Mennidosa on the Little Saskatchewan; while the eighth and ninth moraines extend into regions unknown west of Hudson Bay.

ART. XLIX.—*Preliminary Report on some new marine Tertiary horizons discovered by Mr. J. B. Hatcher near Punta Arenas, Magellanes, Chile;* by ARNOLD E. ORTMANN, Ph.D.

HAVING arrived in Punta Arenas in December, 1897, Mr. J. B. Hatcher directed his attention first to the study of the Tertiary deposits found near the Coal Mines of Punta Arenas. He collected a lot of specimens from these beds, and about the middle of February, 1898, his first shipment of fossils reached Princeton, together with a letter giving stratigraphical notes and a rough sketch of a section of the locality under discussion. The writer has examined the marine fossils of this collection, and thinks it important to give a preliminary report on these beds, since this collection shows that there are represented *two new horizons* different from and older than the Tertiary beds known in Patagonia (Patagonian and Suprapatagonian beds), which contain a marine fauna that is to be regarded as completely new to science.

Although Philippi* has described a couple of species from Punta Arenas and the surrounding country, nothing was known hitherto as to the stratigraphical relations of these fossils. Now, Mr. Hatcher's collection contains a number of Philippi's species, and his notes show conclusively that they are not found in one and the same bed, but belong to *three* different horizons, one of which is apparently identical with Patagonian deposits, while the two others are different and older.

While I do not propose to give a complete geology of these parts—leaving this task to Mr. Hatcher—I may describe the general succession of the beds under discussion, in order to show their relations to each other.

The locality is situated on the bluffs of the northern banks of the Rio de las Minas, which cuts through the strata in a west-easterly direction. The dip of the beds seems to be to the west—quite different from that observed by Mr. Hatcher farther north.†

Mr. Hatcher distinguishes in his notes *five* principal horizons. The *first* (the lowermost) contains only plant-remains (leaves, etc.), the *second* and *third* contain marine shells, the *fourth* represents the Punta Arenas coal, and the *fifth* (the uppermost) contains again marine fossils. He did not send any measurements of the thickness of the respective beds: only the vertical distance of the outcrop of the fifth bed on top of the hills from Punta Arenas is given approximately as 700 feet. Thus

* Die tertiaeren und quartaeren Versteinerungen Chiles, 1887.
† This Journal, vol. iv, November, 1897, pp. 334 and 338.

it seems that the total thickness of these five beds, together with the intermediate, non-fossiliferous strata, amounts to several hundred feet.

Since the *first* and the *fourth* horizons contain only plant remains (the fourth being the Punta Arenas coal, a very black lignite, of which Mr. Hatcher has sent specimens), I shall disregard these beds, and discuss only the horizons II, III and V.

Beginning with the uppermost, the *fifth* horizon, overlying the coal mines, it is to be divided, according to the labels of the specimens, into three subdivisions. Horizon V proper contains most of the fossils: but there are a number of oysters, which are labelled below V, and above V. Thus it seems that the chief horizon V begins and ends with oyster beds.

Now, it is very interesting that the oysters found "above V" agree in every respect with the large oyster of the Cape Fairweather beds discovered by Mr. Hatcher.* This form is *not* found in any of the underlying beds of this section, but it is represented in horizon V *and* "below V" by a form that agrees completely with what I have called *Ostrea philippii*,† which is characteristic for the Suprapatagonian beds of Patagonia (Rio Chalia and Rio Chico).

The list of the fossils found in horizon V proper is the following:

Ostrea philippii Ortm. (= *bourgeoisi* Phil.)
Pectunculus ibari Phil. (= *magellanicus* Phil. = *pulvinatus cuevensis* v. Ih.)‡
Lucina promaucana Phil.
Venus chiloënsis Phil.
Cytherea splendida v. Ih.
Crepidula gregaria Sow. (= *Haliotis imperforata* Phil.)§
Lamna sp. (Tooth).

Disregarding the sharks-tooth, we have *six* species in this bed. *Four* of them (*Ostrea phil.*, *Pectunculus ib.*, *Venus chil.*, *Crepidula gr.*) have been recorded already by Philippi. *Five* species (*Ostrea p.*, *Pectunculus i.*, *Lucina p.*, *Cytherea s.*, *Crepidula g.*) are found in Patagonia, all of them in the Suprapatagonian beds, only two or three also in the Patagonian beds

* See Hatcher, On the Geology of Southern Patagonia, this Journal, vol. iv, November, 1897, p. 345, and Ortmann, On some of the large Oysters of Patagonia, ibid., p. 356.

I no longer believe that this oyster is identical with *O. patagonica* d'Orb. As to the identification of the Patagonian oysters I differ from v. Ihring (Revista Museu Paulista, vol. ii, 1897): but this is not the place to discuss this question in detail.

† See l. c., p. 356, pl. 11, fig. 2.

‡ See v. Ihring, l. c., p. 238, pl. 7, fig. 46, pl. 8, fig 50. The identity of these forms is shown by our series of specimens.

§ *Haliotis imperforata* of Philippi (l c., pl. 12, fig. 2) is nothing else than a giant *Crepidula gregaria.*

(*Ostrea p.*, *Lucina p. ?*, and *Crepidula g.*). Thus it seems—although the number of fossils is quite small—that the identity of our *fifth horizon* with the *Suprapatagonian beds* is warranted, especially, if we take into consideration that some of the species (*Ostrea*, *Pectunculus*, *Crepidula*) are very characteristic forms of these deposits.

In the oyster bed "below V" only oysters of the type of *O. philippii* are found: a single upper valve from the same bed suggests also the presence of *O. hatcheri* Ortm.,* but this valve is not sufficient to make the identification certain.

The beds discussed above are separated from the third horizon by the coal underlying the fifth horizon and its subdivisions. The *third* horizon contains the following fossils:

Ostrea torresi Phil. (abundant).
Cardita spec. nov.
Venus spec. nov. (No. 1) (also in horizon II).
Venus spec. nov. (No. 2).
Cytherea (?) *spec. nov.*
Glycimeris spec nov.
Patella spec. nov.†
Trochus (*Calliostoma*) *spec. nov.*
Trochita costellata Phil. (also in horizon II).
Natica chiloënsis Phil. (also in horizon II).

The difference of this fauna from that of horizon V is very striking. None of the species has been found in Patagonia, and most of them are new to science. *Ostrea torresi* is the only one previously recorded from this locality, and it is the only abundant form, the others being much rarer. *Trochita costellata* has been recorded from Lebu, Chile, and *Natica chiloënsis* from the island of Chiloë, both localities being regarded as of the age of the "Navidad Stufe" of Steinmann.‡ The latter two species as well as *Venus spec. nov.* (No. 1) are also represented in the second horizon.

The *second* horizon, the lowermost in the series containing marine fossils, has yielded the following species:

Ostrea sp. ? (only upper valves).
Venus spec. nov. (= No. 1) (also in horizon III).
Dosinia complanata (Phil.)
Glycimeris ibari (Phil.)
Lutraria spec. nov.
Turritella spec. nov. (very abundant).
Trochita costellata Phil. (also in horizon III).

* See l. c., p. 355, pl. 11, fig. 1 (= *O. percrassa* v. Ih., l. c, p. 221).
† Or *Acmæa spec. nov.*
‡ See Philippi, l. c., p. 249 and 250; Steinmann and Moericke, in Neues Jahrbuch f. Miner., etc, Beil. x, p. 593, 1896.

Natica chiloënsis Phil. (also in horizon III).
Struthiolaria spec. nov.
Actæon chilensis Phil.
Bulla remondi Phil.

This fauna again differs from that found in the third horizon, although there are three species (out of ten) identical. *Glycimeris ibari* is the only form previously recorded. *Five* species (*Dosinia c.*, *Trochita c.*, *Natica c.*, *Actæon c.*, *Bulla r.*) have been found in the Navidad beds of Chile, while none of them has been found in Patagonia.

The list of fossils from Magellanes (Punta Arenas, Skyring Water, etc.) given by Philippi*) contains 17 species, one of which (*Turritella patagonica*) was inserted by a mistake (cf. l. c., p. 77), while *Pectunculus ibari* and *magellanicus* are identical, thus leaving 15 species. *Seven* of these are represented in our collection, namely: 1. *Haliotis imperforata* (= *Crepidula gregaria*, 2. *Venus chiloënsis*, 3. *Panopæa ibari* (= *Glycimeris ibari*), 4. *Pectunculus ibari*, 5. *Ostrea bourgeoisi* (= *O. philippii*), 6. *Ostrea patagonica* (probably = Cape Fairweather oyster), 7. *Ostrea torresi.*

No. 1, 2, 4, 5 and 6 are represented in the fifth horizon, No. 7 in the third horizon, No. 3 in the second horizon.

In connection with the general stratigraphical observations made by Mr. Hatcher, the paleontological facts set forth above seem to warrant the following conclusions:

1. There are represented, on the banks of the Rio de las Minas, near Punta Arenas, *three* different horizons yielding marine fossils, the uppermost of which may be subdivided into three subdivisions, and *two* horizons characterized by plant remains. The characteristic fossils of the series are given in the following table:

Horizon:

V. {
c. Oyster bed, composed of the Cape Fairweather oyster.
b. Marine fossils: *Ostrea philippii*, *Pectunculus ibari*, *Crepidula*, etc.
a. Oyster bed, composed of *Ostrea philippii.*

IV. Punta Arenas coal.
III. Marine bed with *Ostrea torresi.*
II. Marine bed with *Turritella*, *Natica chiloënsis*, *Struthiolaria*, etc.
I. Bed with plant-remains.

2. The marine fossils described by Philippi from this locality

* L. c., p. 251.

come from the horizons II, III, and V, and are not all of the same age.

3. Horizon V closely resembles the Suprapatagonian beds of Patagonia. No conclusive evidence has been found indicating the presence of the true Patagonian beds.

4. The horizons II and III have a few species in common. Both differ entirely from V, none of their species having been found in Patagonia. Thus these two horizons form a deposit that is paleontologically and stratigraphically well separated from the Suprapatagonian beds (and paleontologically also from the Patagonian beds).

5. There are some relations of the horizons II and III to the so-called Navidad beds of Chile (5 species). Since these latter beds show also very many relations to the Patagonian and Suprapatagonian beds, and since of the five Navidad species found near Punta Arenas none has been found in Patagonia, it is very probable that the Navidad series contains a number of horizons of different age, a part of which is to be compared with these two horizons of Punta Arenas, while another part is identical with Patagonian deposits.*

6. Since we have ample reason to consider the Suprapatagonian beds as of *Miocene* age,† the question of the geological age of horizon V seems to be settled. As to horizons II and III, stratigraphical evidence points to an older age, perhaps *Eocene*, and the general character of the fossils does not contradict this assumption. But it is well to be noted that very few, if any, direct confirmations of the Eocene age have been found by a comparison of the species with those of known Eocene faunas. On the other hand, Cretaceous age of these two horizons seems to be out of the question, since no characteristic Cretaceous fossils have been discovered, although such forms (Ammonites) are known from a locality not far away (Port Famine).

I hope Mr. Hatcher will again direct his attention to these beds, and, if possible, settle the question of their relation to the Cretaceous deposits of Port Famine as well as the question of the lack of true Patagonian beds in this region. A complete account of the geology of these parts will be given by Mr. Hatcher after his return from Patagonia.

Princeton University, September, 1898.

* This view is supported by the thickness of the Navidad beds. Darwin gives 800 feet for the cliffs forming the Navidad beds (Geol. Observ. South America, 1846, p. 127).

† Compare Hatcher, l. c., p. 337 ff, and Moericke, l. c., p. 593 and 596.

ART. L.—*The Comparative Value of Different Kinds of Fossils in Determining Geological Age;** by O. C. MARSH.

MORE than twenty years ago, my attention was called to the subject of the difference between the value of fossil Plants, Invertebrates, and Vertebrates, as evidence of the geological age of the strata in which they were preserved. On the comparative value of these different groups of fossils then depended the solution of some grave problems in the geology of the Rocky Mountains. I therefore began a systematic investigation of the subject, and gave the results in an address before the American Association for the Advancement of Science, in 1877.† I stated the case as follows:

"The boundary line between the Cretaceous and Tertiary in the region of the Rocky Mountains has been much in dispute during the last few years, mainly in consequence of the uncertain geological bearings of the fossil plants found near this horizon. The accompanying invertebrate fossils have thrown little light on the question, which is essentially whether the great Lignite series of the West is uppermost Cretaceous or lowest Eocene. The evidence of the numerous vertebrate remains is, in my judgment, decisive, and in favor of the former view.

"This brings up an important point in paleontology, one to which my attention was drawn several years since; namely, the comparative value of different groups of fossils in marking geological time. In examining the subject with some care, I found that, for this purpose, plants, as their nature indicates, are unsatisfactory witnesses; that invertebrate animals are much better; and that vertebrates afford the most reliable evidence of climatic and other geological changes. The subdivisions of the latter group, moreover, and in fact all forms of animal life, are of value in this respect, mainly according to the perfection of their organization or zoological rank. Fishes, for example, are but slightly affected by changes that would destroy reptiles or birds, and the higher mammals succumb under influences that the lower forms pass through in safety. The more special applications of this general law, and its value in geology, will readily suggest themselves."

In the statement I have quoted, I had no intention of reflecting in the slightest degree on the work of the conscientious paleobotanists who had endeavored to solve the problem with the best means at their command. I merely meant to suggest that the means then at their command were not adequate to the solution.

* Abstract of Communication made to Section C, British Association for the Advancement of Science, *Bristol* Meeting, September 9, 1898.

† *This Journal, vol. xiv, pp.* 338–378, November, 1877.

It so happened that one of the most renowned of European botanists, Sir Joseph Hooker, was then in America, and to him I personally submitted the question as to the value of fossil plants as witnesses in determining the geological age of formations. The answer he made fully confirmed the conclusions I had stated in my address. Quoting from that, in his next annual address as president of the Royal Society, he added his own views on the same question.* His words of caution should be borne in mind by all who use fossil plants in determining questions of geological age.

The scientific investigation of fossil plants is an important branch of botany, however fragmentary the specimens may be. To attempt to make out the age of formations by the use of such material alone is too often labor lost, and must necessarily be so. As a faithful pupil of Goeppert, one of the fathers of fossil botany, I may perhaps be allowed to say this, especially as it was from his instruction that I first learned to doubt the value of fossil plants as indices of the past history of the world. Such specimens may indeed aid in marking the continuity of a particular stratum or horizon, but without the reinforcement of higher forms of life can do little to determine the age.

The evidence of detached fossil leaves and other fragments of foliage that may have been carried hundreds of miles by wind or stream, or swept down to the sea-level from the lofty mountains where they grew, should have but little weight in determining the age of the special strata in which they are imbedded, and failure to recognize this fact has led to many erroneous opinions in regard to geological time. There are, however, fossil plants that are more reliable witnesses as to the period in which they lived. Those found on the spot where they grew, with their most characteristic parts preserved, may furnish important evidence as to their own nature and geological age. Characteristic examples are found among the plants of the Coal Measures, in the Cycads of Mesozoic strata, and in the fossil forests of Tertiary and more recent deposits.

The value of all fossils as evidence of geological age depends mainly upon their degree of *specialization.* In the Invertebrates, for instance, a Linguloid shell from the Cambrian has reached a definite point of development from some earlier ancestor. One from the Silurian or the Devonian, or even later formations, however, shows little advance. Even the recent forms of the same group have no distinctive characters sufficiently important to mark geological horizons.

* Proceedings Royal Society of London, vol. xxvi, pp. 441–443, 1877.

If we take the Ammonites as another example from the invertebrates, the case is totally different. From the earliest appearance of this family, the members have been constantly changing, developing new genera and species, each admirably adapted to mark definite zones or horizons, and already used extensively for that purpose.

The Trilobites offer another example of a group of invertebrates ever subject to modification, from the earliest known forms in the Cambrian, to the last survivors in the Permian. They, too, are thus especially fitted to aid the geologist, as each has distinctive features, and an abiding place of its own in geological time.

The above examples are all marine forms, and from their abundance, wide distribution, both in time and space, are among the best of all witnesses in marking the succession and duration of changes in geological history.

If we turn now to the fresh-water Mollusca, we find among them little evidence of change from the Palæozoic forms to those still living, and can therefore expect little assistance from them in noting the succeeding periods during their life-history.

Among the fossil Vertebrates, the same law as to specialization holds good. The value of particular groups as witnesses of geological changes depends largely on their own susceptibility to change, and this is equally true of single genera and species. There are indeed some primitive vertebrates, especially among the Fishes, that appear to have changed little during their geological life. The genus *Lepidosteus* is a good illustration, and hence it is of limited value as evidence of what has taken place during its known geological history. Other fishes, however, are much better witnesses of the past.

The Reptiles as a class offer still better evidence of geological changes, and in many instances may be used to advantage in marking horizons. The great sub-class of Dinosaurs, from their beginning in the Triassic, show marked changes of development throughout the whole of Mesozoic time. During the Cretaceous, highly specialized forms made their appearance, and at the close of this period when all became extinct the last survivors were the strangest of all, reminding one, in their bizarre forms, of the last stages of the Ammonites, their cotemporaries. The Crocodiles, too, show great changes during Mesozoic time, and are thus of much value in determining geological horizons. So, also, are the Pterodactyles, and many other extinct reptiles, each according to the degree of specialization attained.

The Mammals, however, are by far the most important class for marking geological time, as their changes and the high degree of their specialization furnish the particular characters that are most useful to the geologist in distinguishing definite zones, and the more limited divisions of the strata containing their remains. The few mammals known from the Trias are so peculiar that they can only give us hints of what mammalian life then was, but in the Jurassic the many forms now known offer important testimony as to the different horizons in which their remains are found. This is true also of the known mammals from the Cretaceous; all are of special value as witnesses of the past.

During Tertiary time, however, the enormous development of the class of mammals, their rapid variations, and, most important of all, the highly specialized characters they develop, offer by far the best evidence of even the smaller changes of climate and environment that mark their life-history throughout. The ungulates alone will answer the present purpose as an illustration, and even one group, the horses, will make clear the point I wish to bring before you.

Near the base of the Eocene the genus *Eohippus* is found, representing the oldest known member of the horse tribe. Higher up in the Eocene *Orohippus* occurs, and still higher comes *Epihippus*, near the top of the Eocene. Again through the Miocene more genera of horses, *Mesohippus*, *Miohippus*, and others, follow in succession, and the line still continues in the Pliocene, when the modern genus *Equus* makes its appearance. Throughout this entire series, definite horizons may be marked by the genera, and even by the species of these equine mammals, as there is a change from one stage to the other, both in the teeth and feet, so that every experienced paleontologist can distinguish even fragments of these remains, and thus identify the zones in which they occur.

This is true of every group of mammals, although not to an equal extent, so that in this class we have beyond question the best means of identifying the age of Tertiary strata by their fossil remains.

I have thus briefly pointed out some of the evidence on which a decision may be reached as to the value of the different kinds of fossils, Plants, Invertebrates, and Vertebrates, in determining the age of strata. All evidence of this kind is of value, but it is the comparative value of each group that is the important point I wish to emphasize, and I have brought the matter before this Section of the Association in the hope that better understanding on this question may be reached among ologists, in the interest of the science to which we are all voted.

ART. LI.—*On the Families of Sauropodous Dinosauria;** by O. C. MARSH.

THE subclass Dinosauria as known to-day, I have divided into three orders: the *Theropoda*, or carnivorous forms; the *Sauropoda*, or herbivorous quadrupedal forms; and the *Predentata*, also herbivorous, and including several suborders; namely, the *Stegosauria* and *Ceratopsia*, both quadrupedal, and the *Ornithopoda*, containing bipedal bird-like reptiles.†

The principal characters of the order *Sauropoda*, here discussed, may be briefly stated as follows:

Order SAUROPODA.

External nares at top of skull; premaxillary bones with teeth; crowns of teeth rugose, and more or less spoon-shaped; large antorbital openings; no pineal foramen; alisphenoid bones; brain case ossified; no columellæ; postoccipital bones; no predentary bone; dentary without coronoid process. Cervical ribs coössified with vertebræ; anterior vertebræ opisthocœlian, with neural spines bifid; posterior trunk vertebræ united by diplosphenal articulation; presacral vertebræ hollow; each sacral vertebra supports its own sacral rib, or transverse process; no diapophyses on sacral vertebræ; neural canal much expanded in sacrum; first caudal vertebra biconvex; anterior caudals procœlian. Sternal bones parial; sternal ribs ossified. Ilium expanded in front of acetabulum; pubes projecting in front, and united distally by cartilage; no postpubis. Limb bones solid; fore and hind limbs nearly equal; metacarpals longer than metatarsals; femur longer than tibia; astragalus and calcaneum not fitted to end of tibia; feet plantigrade, ungulate; five digits in manus and pes; second row of carpal and tarsal bones unossified; locomotion quadrupedal.

(1) Family *Atlantosauridæ*. A pituitary canal; large fossa for nasal gland. Distal end of scapula not expanded; coracoid quadrilateral. Sacrum hollow; ischia directed downward, with expanded extremities meeting on median line. Anterior caudal vertebræ short, with lateral cavities; remaining caudals solid; chevrons single.

Genera *Atlantosaurus*, *Apatosaurus*, *Brontosaurus*. Include the largest known land animals. Jurassic, North America.

* Abstract of Communication made to Section D, British Association for the Advancement of Science, Bristol Meeting, September 12, 1898.

† The Dinosaurs of North America, Sixteenth Annual Report, U. S. Geological Survey. 84 plates. Washington, 1896.

(2) Family *Diplodocidæ.* External nares at apex of skull; no depression for nasal gland; two antorbital openings; large pituitary fossa; dentition weak, and in front of jaws only; brain inclined backward; dentary bone narrow in front. Scapula with shaft somewhat enlarged at summit. Ischia with shaft expanded distally, directed downward and backward, with sides meeting on median line. Sacrum hollow, with three coössified vertebræ. Anterior caudal vertebræ procœlian, with sides deeply excavated, and chevrons single; median caudals excavated below, with chevrons double, having both anterior and posterior branches; distal caudals elongate, with rodlike chevrons.

Genera *Diplodocus* and *Barosaurus.* Jurassic, North America.

(3) Family *Morosauridæ.* External nares anterior; large fossa for nasal gland; small pituitary fossa; dentary bone massive in front; teeth very large. Shaft of scapula expanded at distal end; coracoid suboval. Sacral vertebræ four in number, and nearly solid; ischia slender, with twisted shaft directed backward, and sides meeting on median line. Anterior caudals solid; chevrons single.

Genera *Morosaurus*, *Camarasaurus* (?) (Amphicœlias). Jurassic, North America and Europe.

(4) Family *Pleurocœlidæ.* Dentary bone constricted medially; teeth with crowns like those of *Diplodocus.* Cervical vertebræ elongate, centra hollow, with large lateral openings; sacral vertebræ solid, with lateral depressions in centra; caudal vertebræ solid; anterior caudals with flat articular faces, and transversely compressed neural spines; median caudal vertebræ with neural arches on front half of centra. Ischia with compressed distal ends, and sides meeting on median line.

Genera *Pleurocœlus*, *Astrodon* (?). Jurassic, North America and Europe. Include the smallest known *Sauropoda.*

(5) Family *Cardiodontidæ.* Teeth of moderate size. Upper end of scapula expanded; humerus elongate; fore limbs nearly equaling hind limbs in length. Sacrum solid; ischia with wide distal ends, and sides meeting on median line. Caudal vertebræ biconcave; median caudals with double chevrons.

Genera *Cardiodon* (Cetiosaurus), *Bothriospondylus*, *Ornithopsis*, and *Pelorosaurus.* European, and probably all Jurassic.

(6) Family *Titanosauridæ.* Fore limbs elongate; coracoid quadrilateral. Presacral vertebræ opisthocœlian; first caudal vertebræ biconvex; remaining caudals procœlian; chevrons open above.

Genera *Titanosaurus* and *Argyrosaurus.* Cretaceous (?), dia and Patagonia.

ART. LII.—*A Biotite-tinguaite Dike from Manchester by the Sea, Essex County, Mass.*; by ARTHUR S. EAKLE.

THE dike described in this paper cuts through the augite-syenite of Gales rocks, 200 yards south of Gales Point, Manchester, and was discovered in July, 1896, by Mr. J. H. Sears, while investigating the rocks of that vicinity. The writer has not seen the dike, and all of the data regarding its occurrence, and the material for the petrographical and chemical study, has been very kindly supplied by Mr. Sears. "The dike is 6 inches wide and is exposed for 20 feet, cutting the augite-syenite in a nearly horizontal position, six feet below the surface of the mass of syenite. It is only exposed at low water, as at high tide the entire mass of syenite is submerged." The occurrence of this ægirine dike in the immediate vicinity of the tinguaite dike at Pickards Point, which was first described by Sears* and lately shown to be an analcite-tinguaite by Washington,† might naturally lead to the supposition that the two dikes would be similar in many respects, yet both macroscopically and microscopically they are quite dissimilar rocks.

The rock has a greenish-gray color and a slightly greasy luster, like tinguaites and rocks rich in nepheline. Small phenocrysts of feldspar are visible in the somewhat compact groundmass, and also much magnetite, mixed with biotite, occurs in brownish-black patches, giving the rock a mottled appearance. The structure is compact, holocrystalline, the rock resembling a phonolite, breaking with an even fracture and weathering to a light gray color.

Under the microscope the principal constituents are seen to be feldspathic laths and plates with much nepheline and less amounts of ægirine, magnetite and biotite. Besides these prominent minerals, hematite, a little sodalite, a few apatite and zircon needles, and minute sections of purple fluorite are present.

The feldspar is the most abundant constituent and predominates in lath-shaped sections, most of which have a broken, ragged appearance, due to frayed-out ends and a fibrous structure. This fibrous appearance is evidently the result of lamellar intergrowths of the soda and potash feldspars, microcline and albite, forming microcline-microperthite. Some of the broader sections show a rather coarse intergrowth of the two feldspars, giving extinctions on different parts corresponding respectively to those of microcline and albite. The character-

* J. H. Sears, Bull. Essex Inst., vol. xxv, 4, 1893.
† This Journal, IV, vol. vi, p. 182, 1898.

istic moirè appearance of anorthoclase is lacking, the sections showing multiple extinctions and appearing more as perthitic intergrowths than as homogeneous mixtures of the two feldspars. Carlsbad twinning is quite common. The visible phenocrysts are brachypinacoidal plates of albite which show basal and prismatic cleavage cracks.

Nepheline is next to the feldspars in amount and plays the role of quartz, filling the interspaces formed by the network of feldspar laths. Having been the last mineral to form, most of it is consequently in xenomorphic, angular sections, but here and there a well-defined hexagonal plate is seen. The sections are mostly altered to a grayish, muddy, granulated material which is apparently a mixture of nepheline with kaolin and very fine granular quartz, the alteration proceeding to a hydrous aluminium silicate, with a separation of some free silica, rather than to a zeolite. They still retain their index above that of the neighboring feldspar and gelatinize to some extent with HCl, as shown by fuchsin staining.

Ægirine is disseminated in the rock, in fragments and small crystals, in sufficient amount to give the rock its slightly greenish cast. Its crystallization preceded that of the feldspars and it is now present as rounded crystals or broken, irregular fragments. The sections vary from deep grass-green to almost colorless, and the more deeply colored show a marked pleochroism, $\mathfrak{a}$ = bluish green, $\mathfrak{b}$ = grass green, $\mathfrak{c}$ = greenish yellow; the axis of greatest elasticity lies nearest c, and the extinction is practically parallel in most of the sections.

Magnetite is common and marks the remains of plates of a former dark silicate. Most of this original silicate has entirely disappeared, leaving only the black patches of secondary magnetite, but an occasional section shows a greenish-brown mineral between the heavy black borders, which from its absorption, parallel extinction, and characteristic shimmer, is evidently biotite or perhaps lepidomelane. From the similarity of all the black sections it is reasonable to infer that they were originally this biotite, and since the analysis shows so little magnesia in the rock, the biotite must have been very poor in this oxide and high in iron. Washington notes the poverty of magnesia in all of the rocks of Essex County, so far analyzed by him.

Sodalite is seen in small, colorless isotropic sections of low refraction and showing dodecahedral cleavage. The amount however is much too small to account for all of the chlorine in the analysis, and it is quite probable that most of the chlorine is due to impregnation from the sea water. None of the small amount of isotropic mineral in the slide is believed to be analcite, and the dike can hardly be included in the same class with the one at Pickards Point.

The structure of the rock differs from that of a typical tinguaite, in that the component feldspar and ægirine minerals do not occur as needles, but as much stouter lath-shapes and prismatic crystals, indicating a slower rate of cooling of the magma and thus producing a phase of tinguaite much less dense and more holocrystalline than common. The rock is classed here as a biotite-tinguaite, yet from the presence of many feldspar sections tabular to M, it can as well be considered a phase of sölvsbergite. It stands intermediate between a quartz-free nepheline tinguaite and a nepheline-ægirine sölvsbergite; such a rock is described by Brögger from a dike between Tjose and Åklungen.*

The analysis gives:

SiO_2	60·05
TiO_2	0·11
Al_2O_3	19·97
Fe_2O_3	4·32
FeO	1·04
MnO	0·79
CaO	0·91
MgO	0·23
K_2O	3·24
Na_2O	7·69
H_2O 110°	0·15
H_2O ig.	1·26
Cl	0·28
	100·04

The specific gravity determined by the balance is 2·708.

Access to the dike is very difficult, and all of the specimens obtained come from near the surface and have weathered enough to make it difficult to estimate, even approximately, the relative proportions of the mineral contents from the chemical analysis. The nepheline and biotite show the greatest amount of alteration and the rock has apparently lost some of its alkalies and iron from the change, through its exposed condition. The amount of silica and alumina is more than sufficient to combine with the alkalies to form the alkali minerals, and the excess is present in the form of kaolin and secondary quartz. Fully 20 per cent of the slide appears to be nepheline, yet the percentage of soda will only allow for about one-half of this amount, and 14 per cent only of the rock is soluble in HCl. A calculation from the percentage composition, with due regard to the microscopical estimation, gives the following as an approximate mineral composition of the rock in its present state:

* Die Eruptivgesteine des Kristianiagebietes, Part I, p. 99.

47·16	$Na_2Al_2Si_6O_{16}$	67·28 per cent feldspar.
16·68	$K_2Al_2Si_6O_{16}$	
3·44	$CaAl_2Si_2O_8$	
9·61	$Na_6K_2Al_8Si_9O_{34}$	20·32 nepheline, kaolin and quartz.
8·09	$H_4Al_2Si_2O_9$	
2·62	SiO_2	
6·00	$Na_2Fe_2Si_4O_{12}$	6·00 ægirine.
2·90	biotite.	6·40 biotite and iron oxides.
3·50	$Fe_2O_3(FeMn)O$	
100·		

The remaining minerals, sodalite, apatite, zircon and fluorite, would probably form less than one per cent of the rock. The same relative proportions of the minerals in a perfectly fresh rock would require about one and one-half per cent more of combined alkalies, with a corresponding decrease in the combined silica and alumina.

Mineralogical Laboratory, Harvard University, September, 1898.

ART. LIII.—*Descriptions of new American Actinians, with critical notes on other species*, I.; by A. E. VERRILL. *Brief Contributions to Zoology from the Museum of Yale College.* No. LVIII.

Sagartia Luciæ, sp. nov. Figure 1, p. 497.

A SMALL, very smooth, highly contractile species. In usual expansion the column may be cylindrical; its height may be less than its diameter or twice as great; it is often distinctly fluted, but has no trace of adhesive suckers. Cinclides are not visible, but white acontia are emitted freely from the sides of the body, irregularly, and from the mouth. The column is usually dark green, or olive-green, often tinged with orange, and is striped with 12 (sometimes 24) narrow bright orange or white lines, corresponding to the 12 larger tentacles and mesenterial interspaces.

Tentacles, in the larger examples, 60 to 84, more commonly 48, arranged in four ill-defined rows, long, slender, tapered, capable of sudden contraction; the length of the 12 inner ones is often twice the diameter of the body or more; the two directives (a, a') are slightly longer than the other primaries. The tentacles are pale green or greenish white, sometimes tinged with salmon, and sometimes specked with white; the larger ones are often darker green at base, and whitish on the inner side of the base, especially the directives.

Disk changeable, flat, concave or convex, greenish, marked with narrow dark radial lines and crossed by a conspicuous bar of flake-white, in line with and including the bases of the directive tentacles, and embracing the sides of the mouth; smaller radial white spots may stand in front of other tentacles. Lips light red, with several small lateral folds and two gonidial grooves.

Height of column usually about ·25 inch (5 to 8^{mm}); diameter 4 to 6^{mm}; length of tentacles 6 to 10^{mm}.

New Haven, Conn., to Woods Holl, Mass., in tidal pools, from half-tide to low-water mark, both freely exposed and concealed under stones and in crevices.

It is very abundant in the small tide-pools situated at about half-tide on the ledges of "Outer Island," near New Haven, where I have studied it during six seasons. In some of these pools the water is not more than one or two inches deep and in winter it freezes to solid ice each day; while in summer it becomes heated to 95° F., or even more, without injury to this apparently delicate actinian. Moreover, when rain falls during the recession of the tide, the sea-water in these small pools is

washed away and replaced by fresh water for several hours, destroying most other kinds of marine life, but apparently without injury to this species. At least, I have found them as active as usual the next day. Such pools are also exposed to heavy seas and the pebbles and cobble stones that often fill them are violently tossed about by the waves, and yet I have often found the actinians as lively as ever immediately after the severest storms.

It is, therefore, one of the hardiest species known. It expands freely and almost constantly in confinement.

In the upper tide-pools it is often associated with young oysters and mussels, and with the common rock barnacle (*Balanus balanoides*). The English periwinkle (*Littorina littoralis*) also abounds in the same pools. This *Sagartia* is often attached to the mussels and oysters, as well as to the exposed ledge and under sides of stones, etc. Sometimes it is found on *Chondrus crispus* and other algæ. Dr. W. E. Coe has found it in New Haven harbor, and informs me that he also found it common at Woods Holl, Mass., this season, but during the nine seasons that I spent at that station studying the fauna, between 1871 and 1887, I did not find it, though careful search was made every season for small organisms in suitable localities. The same is true in respect to the region about New Haven, which was carefully searched by me, during many years, from 1865 to 1890, without finding this species. So we must conclude that it has very much increased in numbers in this region within a few years, like several other species. It may have been introduced from further south, on the oysters that are annually brought north, in large quantities, and planted in our waters.

My attention was first called to this species, as something new, in 1892, by my young daughter, Miss Lucy L. Verrill, for whom I have named it. She found it in the tidal pools at Outer Island, Conn. It was then much less abundant that at the present time.

Specimens collected early in November often contain numerous small ciliated embryos, which may be seen swimming about inside the translucent tentacles.

This species belongs to that section of the genus *Sagartia* for which Gosse proposed (1860) the name *Thoë*, characterized by the smoothness of the column, no adhesive suckers being visible. Our species is entirely smooth, and I have never seen any adherent particles of sand or mud.

The typical species of *Sagartia* (*S. miniata*, etc.) have numerous small adhesive papillæ or suckers on the upper part of the column. The same is true of the genus or subgenus *Cylista* Gosse, 1860. Additional figures of this species have been prepared for a subsequent paper.

Sagartia (Thoë) leucolena Ver.

Sagartia leucolena Verrill, Proc. Boston Soc. Nat. Hist., x, p. 336, 1865; Amer. Naturalist, ii, p. 261; Rep. on Invert. of Vineyard Sd, etc., pp. 444, 329, etc., pl. 38, fig. 284, 1874; Radiata North Carolina, this Journal, iii, p. 436, 1872.
Cylista leucolena Andres, Attinie Golfes Neapel, p. 151, 1884.

This species also has a smooth column, without any adhesive suckers, though the scattered cinclides show distinctly, as pores, when living specimens are viewed by transmitted light. Therefore it does not belong to *Cylista*, to which Andres referred it, for the latter has very evident suckers.

It is easily distinguished from *S. Luciæ* by its very elongated, often flaccid, column, which is translucent flesh-color or salmon-color, and by the pale translucent disk and tentacles, without any strong markings. This species lives in the same region as the preceding and is often associated with it, near low-water mark, under stones. It ranges southward to North Carolina.

Actinia Bermudensis, sp. nov.

Column smooth, changeable in form, usually, in expansion, about as high as broad, often broader than high, capable of contracting to a low hemispherical form, with tentacles entirely concealed, but it contracts rather slowly. There is a distinct, strong, submarginal fold, just below the acrorhagi. These are marginal, very large, hemispherical or verruciform, not very numerous (about 24), bright blue. They are often concealed by the fold below them. Tentacles numerous, usually 72 to 96, rather stout, elongated, arranged in several circles in the larger examples; when fully extended the longest are often as long as the diameter of the disk, or even exceed it. The mouth is large with a strong gonidial groove at each end, bordered by prominent lobes; sides of mouth with numerous small folds.

Color of column usually bright cherry-red, sometimes dark red, crimson, or rose-red. Tentacles paler than the column, but usually of the same general color, or brighter. Lips often bright red or carmine. Acrorhagi bright blue. Disk similar to the tentacles.

Height of column up to 1·5 inches (30 to 40^{mm}); diameter up to 1·75 inches or more (40 to 50^{mm}).

Bermuda Islands on the under side of large stones at and above low-water mark, especially at Bailey's Bay and Castle Harbor. (A. E. Verrill and party, 1898.)

Var. *ferruginea*.

A variety, apparently of the same species, was occasionally observed, in the same localities, in which the color of the col-

umn was plain yellowish brown; tentacles a lighter tint of the same. Acrorhagi without differentiated pigment and hence not conspicuous. The form of the body and tentacles were the same as in the typical variety.

This species closely resembles some of the varieties of the common European species, but appears to differ especially in the less numerous and larger acrorhagi, and in the fewer and larger tentacles. Figures of this species will soon appear in the Trans. Conn. Acad. Science.

Epicystis Ehr., Corall. rothen Meeres, p. 44, 1834.

Phymanthus (pars) Andres, Attinie Golfes Neapel, p. 285, 1884 (*non* Edw.).

The generic name *Epicystis* was proposed for the *Actinia crucifera* Les., *A. ultramarina* Les., and *A. granulifera* Les., the first being put in Sect. *a.* Therefore it is necessary to take the former as the type of the genus, which is evidently entirely distinct from the true *Phymanthus.*

Epicystis crucifera Ehr., Corall. rothen Meeres, p. 44, 1834.

Actinia crucifera Leseur, Journ. Acad. Nat. Sci. Philad., i, p. 174, 1817.
Phymanthus crucifer Andres, Attinie Golfes Neapel, p. 286. McMurrich, Actinaria Bahama Is., p. 51, pl. ii, fig. 1, general, pl. iv, figs. 6–11, anatomy, 1889; Duerden, Journ. Inst. Jamaica, ii, p. 452, 1898.

This species is common in crevices and holes of the coral reefs of Bermuda, where I collected specimens which were 6 to 8 inches in diameter of disk when fully expanded. It is a very handsome species, when living.

Edwardsia Leidyi, sp. nov. Figures 2, side, 3, aboral end.

Edwardsia, sp. Mark, Embryol. Mon., Mem. Mus. Comp. Zoöl., ix, pl. xii, figs. 24–33, 1884 (development and structure).

Column, in expansion, very long, slender, often flattened, soft. In the oldest stages observed by me it was still without external covering, but Prof. Mark figures it in one case with a loose and imperfect coating. Tentacles, in the oldest parasitic stage seen by me, eight short, obtuse; in a later stage sixteen have been observed and figured by Prof. Mark. Messenteries eight, in the largest specimens studied.

Color of column whitish, flesh-color, or pale rose, translucent, with eight longitudinal stripes of white or pale salmon-color.

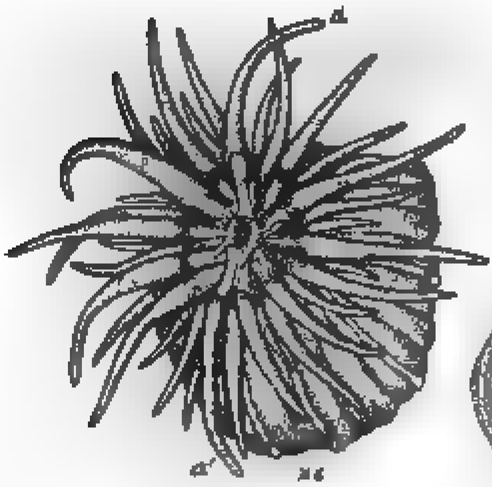
Length while parasitic, in extension, up to 1 inch or more (20 to 30^{mm}), diameter $\cdot5$ to $1\cdot5^{mm}$.

The young, in various stages of growth, are frequently found as parasites in the interior of a common ctenophorus jelly-fish (*Mnemiopsis Leidyi* Ag.) on the southern coast of New England. It is common at Wood's Holl, Mass., and Newport, R. I. Several specimens of different ages are often found together.

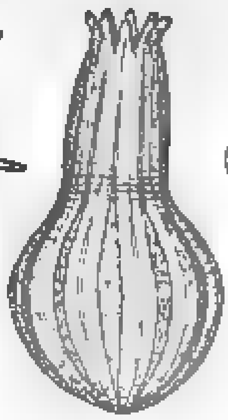
The completely developed state of this species is probably unknown. Prof. Mark has figured a free stage, presumably raised from the parasite, with sixteen tentacles, in two unequal cycles, and with a rudimentary mucous sheath. The latest stages raised by me from the parasite had but eight tentacles and did not form a sheath, though it was then considerably longer than the young of *E. lineata* V. having 18 tentacles. Hence I do not think it can be the young of the latter, as Prof. Mark suggested. Moreover, its colors are entirely different and the tentacles are much shorter and more obtuse. It is more likely to be related to *E. pallida* V. than to any of the other known species. It resembles some of the European species that are also parasitic in jelly-fishes, while young. It is very contractile and is protean in form.

This parasite was first noticed by Mr. A. Agassiz in 1865, North Amer. Acal., p. 23, but he did not recognize it, at that time, as an actinian. I have a good series of drawings of it made in 1881–1883, showing its generic characters. Figs. 2 and 3 are by J. M. Blake, from life.

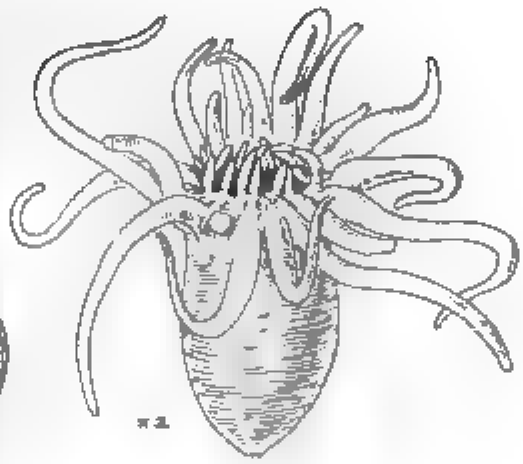
1.



2.



4.



Dactylactis viridis, sp. nov. Figures 4, 5, 6.

A free-swimming cerianthid found in the Gulf Stream.

Column smooth, very changeable in shape, usually about twice as long as broad, in life; sometimes pear-shaped with the basal region swollen and rounded at the end; sometimes top-shaped, with the basal end pointed; sometimes most swollen in the middle. Usually there are no flutings, when expanded, but in some cases, when the base is swollen, it shows slight invections. The margin is plain and simple, tentaculate; there appears to be a terminal pore.

Outer tentacles, in the largest two observed, 18 and 20, in a single circle, only slightly unequal in length and size, long, slender, regularly tapered, usually longer than twice the diam-

eter of the body, sometimes nearly thrice as long, in living specimens. Oral tentacles nearly equal in number to the outer ones, varying in length from one-fourth to one-half the length of the latter, smaller and more delicate, tapered, carried erect, or nearly so, while the outer tentacles are widely divergent or often recurved and bent in various directions.

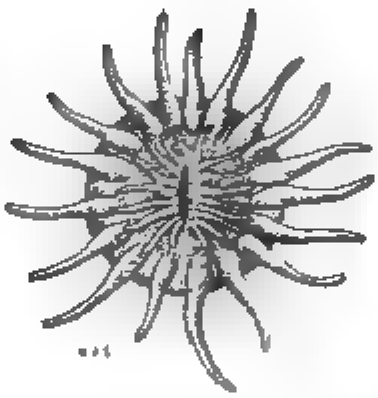
Color in life, light olive-green; tentacles translucent pale greenish.

Length of column about ·5 inch (10 to 12^{mm}); diameter about ·25 inch (5 to 7^{mm}); length of longest tentacles about 14^{mm}.

Taken several times by the "Albatross." Among other places, at sta. 2587, N. lat. 39° 02′, W. long. 72° 38′; sta. 2749, N. lat. 39° 42′, W. long. 71° 17′, Sept. 19, 1887; surface temperatures 71° and 67° F.

5.

6.



3.

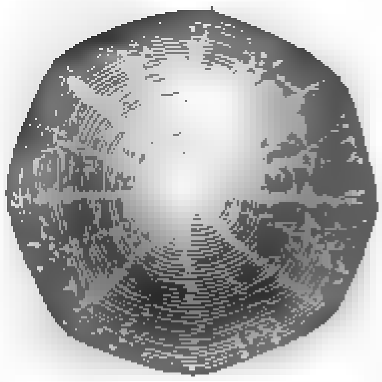


Fig. 4 is by J. M. Blake; figs. 5, 6, by A. H. Baldwin, both from life.

This species somewhat resembles *D. digitata* Van Beneden, taken near Bermuda (Plankton Exp. Anthozoa, p. 94, pl. vii, figs. 19–22, 1898), but the latter is much smaller, column $6{\cdot}42^{mm}$ long in preserved specimens, and had 14 marginal and 10 oral tentacles. Possibly it may be a younger state of the same species. It will need specimens intermediate in size to determine this. It is probably immature.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On Hyponitrous acid and Hyponitrites.*—According to KIRSCHNER'S investigations, the hyponitrites may be prepared readily from potassium oxyimidosulphonate. Fifty grams of this salt is dissolved in 35^{cc} of boiling water. After cooling by means of ice, the solution is mixed with 10^{cc} of a concentrated sodium hydrate solution (1 : 1), the temperature of the mixture not being allowed to rise above 30°. After cooling to 10°, 90^{cc} more of the sodium hydrate solution are added, the mixture is heated to 50° for half to three-quarters of an hour, and is then poured into a liter of water. This solution contains sulphate, sulphite and hyponitrite of sodium and also a little undecomposed oxyamido-salt and some hydroxylamine. By adding yellow mercuric oxide, these last substances are destroyed. The liquid, after filtering, is made up to four liters and silver nitrate is added so long as a light yellow precipitate, consisting of silver hyponitrite, is produced. By the addition of barium, strontium or calcium nitrate to a strongly alkaline solution of silver hyponitrite, a precipitate is obtained of the corresponding hyponitrite. It is washed with alcohol and ether and dried on filter paper. All of these salts are slightly soluble in water, have an alkaline reaction and evolve nitrous oxide with acids. The calcium salt is the most stable. It loses its crystal water with difficulty and is not affected at the ordinary temperature by carbon dioxide. They are represented by the formulas $Ba(NO)_2 . (H_2O)_4$, $Sr(NO)_2 . (H_2O)_5$ and $Ca(NO)_2 . (H_2O)_4$ respectively. On adding lead acetate to the sodium salt in alkaline solution, a yellowish-white precipitate of basic lead hyponitrite is produced; which on treatment with acetic acid yields the normal salt $Pb(NO)_2$, as a yellow crystalline powder, which explodes on heating. Copper sulphate added to sodium hyponitrite gives, on treatment with ammonia, a green amorphous powder having the composition $Cu(NO)_2 . Cu(OH)_2$. Silver hyponitrite $Ag_2(NO)_2$ is obtained in crystals from a strong ammonia solution. It is decomposed by hydrogen chloride, yielding hyponitrous acid. The free acid does not decolorize an iodine solution nor does it set free iodine from potassium iodide. Bromine oxidizes it to nitric acid, though the reaction is not a quantitative one.—*Zeitschr. anorg. Chem.*, xvi, 424–437, 1898. G. F. B.

2. *On Experiments with Helium.*—It has been shown by TRAVERS that when an electric discharge is passed through a Plücker tube containing helium at a pressure of about three millimeters, the electrodes being of platinum, a reddish-yellow glow at first appears, which, passing through shades of yellow and green, finally becomes the phosphorescent glow characteristic of a vacuum. Evidently these changes are due to the gradual absorption of the helium by the platinum which has been deposited by

means of the spark on the walls of the tube; since on heating, the helium is again liberated and the colors successively appear in the inverse order. The best defined line, obtained when the green glow is most intense, has the wave length 5015·6. And if now the still remaining gas is removed, and the tube is gently heated, the absorbed gas is set free and the greenish glow reappears. It would appear therefore that the glow is not due to the last absorbed portion of helium, but comes solely from the lowering of the pressure arising from the absorption. Moreover, the author finds that while hydrogen, nitrogen and gaseous carbon compounds, like helium, are more or less readily absorbed when sparked in presence of platinum electrodes, argon is taken up only in very small amount. And he has taken advantage of this fact to separate helium from argon; the process succeeding when only 2 per cent of helium is present. By means of a Sprengel pump, a mixture of these gases is kept in circulation at 3^{mm} pressure, through a Plücker tube kept cool by a water jacket, for six hours. And now, on removing the residual gas, and heating the tube, the helium which is obtained contains only a trace of argon.—*Proc. Roy. Soc.*, lx, 449–453, 1897. G. F. B.

3. *On Calcium nitride.*—The recent noteworthy address of Sir Wm. Crookes as President of the British Association has given increased interest to every proposed process for rendering the nitrogen of the atmosphere available in agriculture. A purely chemical process of this sort has now been proposed by MOISSAN in connection with his production of metallic calcium.* In contact with nitrogen at the ordinary temperature, calcium undergoes no change. But as the temperature is raised, the metal changes from white to yellow, until, at a low red heat, it takes fire and burns in the nitrogen, absorbing it with great rapidity, and giving a bronze-colored nitride. The best result is obtained by placing the calcium in a boat of nickel, placed within a tube of the same metal, through which is sent a current of pure and dry nitrogen. Under the microscope, calcium nitride appears in the form of small transparent crystals yellowish-brown in color, having a density of 2·63 at 17°, and fusing at 1200° approximately. Heated in hydrogen to redness, ammonia is evolved with production of hydride. Chlorine decomposes it with incandescence giving the chloride. It burns in the air, and in oxygen, even below a red heat. Mixed with carbon and heated to 800° calcium nitride suffers no change. But in the electric furnace it is converted into calcium carbide. If the mixture be heated to 1200°, a small quantity of cyanide is produced. Heated to bright redness in a current of nitrogen dioxide, it is converted with incandescence into calcium oxide and nitrogen. In the absence of water, acids have no action on the nitride. Anhydrous alcohol gives calcium ethylate and ammonia. Thrown into water, it decomposes it with effervescence, producing ammonia and calcium

* This Journal, IV, vi, 428, November, 1898.

hydrate. Its composition was determined (1) by weighing the boat before and after converting the calcium into nitride; and (2) by decomposing a weighed quantity of the nitride with water. Four experiments gave 18·37, 18·21, 18·81 and 18·17 per cent of nitrogen and 81·63, 81·79, 81·19 and 80·49 of calcium; the formula C_3N_2 requiring 18·92 of N and 81·08 of Ca. The author thinks that the production of calcium nitride industrially will solve the problem of the manufacture of ammonia from the atmosphere.—*C. R.*, cxxvii, 497–501, October, 1898. G. F. B.

4. *On Sodium sub-oxide and peroxide produced by combustion.*—The composition and the heat of formation of the sodium oxides produced by combustion has been studied by FORCRAND. About 20 grams of sodium was melted in a tubulated glass retort, provided with a spherical condenser, also tubulated; a current of dry air, free from carbon dioxide, being passed through the apparatus. A little above its fusing point the sodium became covered with a gray layer, which soon increased to form voluminous arborescent gray masses. If the operation be continued the gray mass takes fire, producing white vapors, which condense both in the retort and the receiver, leaving a yellowish porous mass which becomes nearly white on cooling. The three products were then analyzed. The gray mass gave 81·88 per cent of sodium and 0·1512 gram evolved $22·05^{cc}$ of hydrogen when placed in water; whence it was composed of 96·26 per cent of the sub-oxide Na_3O mixed with 3·74 per cent of sodium. The white snow condensed in the cooled receiver gave 58·13 per cent of sodium, corresponding to the formula Na_2O_2, which requires 58·97. The white powder in the retort was also Na_2O_2, with a trace of moisture. The yellowish-white residue gave 64·24 and 60·18 per cent of sodium in two samples; and hence was a mixture in variable proportions of Na_2O and Na_2O_2. Heated again in a current of dry air, it was converted into Na_2O_2 with a trace of moisture. No trioxide Na_2O_3 apparently was formed in this reaction.

In a subsequent paper, the author gives the results of his experiments to determine the heat of formation of these oxides. He finds for the sub-oxide Na_3O, the following equation:

$$Na_3 \text{ solid} + O \text{ gas} = Na_3O \text{ solid} \quad + 101·57 \text{ cal.}$$

For the dioxide, Na_2O_2

$$Na_2 \text{ solid} + O_2 \text{ gas} = Na_2O_2 \text{ solid} \quad + 119·79 \text{ cal.}$$

And for the oxide Na_2O

$$Na_2 \text{ solid} + O \text{ gas} = Na_2O \text{ solid} \quad + 100·40 \text{ cal.}$$

—*C. R.*, cxxvii, 364–366, 514–516, August, October, 1898.

G. F. B.

5. *On Aluminum nitride.*—It has been pointed out by FRANCK that aluminum nitride is obtained when an intimate mixture of finely divided aluminum and calcium carbide is heated in a porcelain crucible by means of a blast, with free access of air. The product contains 15 to 20 per cent of nitrogen. Moist air decom-

poses it slowly, boiling water more rapidly, and alkalies very readily, with production of ammonia. A better yield is obtained by passing nitrogen over a mixture of aluminum and dry calcium hydrate.—*J. Chem. Soc.*, lxxiv, ii, 377, August, 1898. G. F. B.

6. *On Enantiomorphism.*—As is well known, enantiomorphous substances are divisible into two classes, intermolecular and intramolecular; i. e., those in which this property is determined by the arrangement of the molecules, and those in which it is determined by their structure. The first class, to which belong quartz and sodium chlorate, are not optically active in solution, though their crystals rotate the plane of polarization. The second class, to which belong all compounds containing an asymmetric carbon atom, are active in the amorphous or liquid state as well as when crystallized. But while the latter must invariably give crystals which are either right-handed or left-handed, there appears no reason why the former should give crystals of the one sort in preference to those of the other. KIPPING and POPE have studied the crystals of sodium chlorate deposited from pure aqueous solutions to ascertain whether the ratio of dextro- to-lævo-sodium chlorate is in fact unity. About 200^{cc} of a saturated solution of this salt was placed in a shallow glass crystallizing dish and allowed to evaporate spontaneously. Each crystal developed apart from its fellows as a right-angled prism; and when they were about 5^{mm} on a side, they were removed from the liquid and the sign of the circular polarization was determined by examination in a polarizing microscope with an inch objective. If the analyzer had to be turned to the right to give extinction, the crystal was dextro-rotatory; and *vice versa*. In only two cases out of 46 crystallizations were equal numbers of dextro- and lævo-rotatory crystals deposited. But the mean percentage value in all the 46 experiments gave 50·83 of dextro crystals; while the weighted mean, in which allowance is made for the total number of crystals obtained, gave 50·08, with a probable error of 0·11. It appears therefore that on allowing sodium chlorate to crystallize spontaneously from pure aqueous solutions, equal numbers of the enantiomorphously related crystals, on the average, are deposited. The authors then took up the question whether, if the crystallizing sodium chlorate solution contained an enantiomorphous substance of the second class, i. e., containing an asymmetric carbon atom, such as dextroglucose for example, there would be the same tendency, aside from the solubility, for dextro- as for lævo-sodium chlorate to crystallize. For this purpose they used solutions containing dextrose, mannitol and dulcitol and found the weighted means to be 31·75, 40·55 and 51·27 respectively. Whence they conclude that on crystallizing a substance which is not enantiomorphous in the amorphous state in presence of one which is so, the average ratio of the crystals of each sort deposited may be made to differ from unity.—*J. Chem. Soc.*, lxxiii, 606–617, August, 1898. G. F. B.

7. *The Doctrine of Energy; a Theory of Reality.* By B. L. L. 12mo, pp. x, 108. London, 1898 (Kegan Paul, Trench, Trübner & Co.).—An argument in favor of dropping Matter as an entity and making Energy the sole basis of Metaphysics. It appears to us quite inconclusive. G. F. B.

8. *Gravitation constant and mean density of the earth.*—The experiments on this subject begun in Spandau in 1884, at the expense of the Königliche Akademie der Wissenschaften and with the aid of the German government, have now been brought to a conclusion. The complete account of the work appears in the proceedings of the K. Akad. d. Wissenchaften of Berlin. The method consisted in double weighing in two scale pans, separated by a connection 226^{cm} long. The authors, F. RICHARZ and O. KRIGAR-MENZEL, give as their first result

$$\Delta = (5{\cdot}505 \pm 0{\cdot}009)\ \frac{g}{cm^3}$$

The results obtained by previous observers are as follows:

Observer.	Method.	Δ	Prob. Error.
Cavendish	Torsion balance	5·45	
Reich	"	5·49—5·58	
Baily	"	5·67	
Cornu and Baille	"	5·56 5·50	
Ph. v. Jolly	Balance with long supports	5·692	±0·068
J. Wilsing	Pendulum apparatus	5·594	±0·032
"	Pendulum apparatus	5·577	±0·013
J. H. Poynting	Balance	5·4934	
C. V. Boys	Improved torsion balance	5·5270	

The German investigators F. Richarz and O. Krigar-Menzel believe that of the above the results of Wilsing, Poynting and Boys are the most accurate. Under certain assumptions Poynting's final result would have a less probable error than that of the authors. Boys estimates that his best result has a probable error of ±0·002. The probable error of Richarz and Menzel is 1·6 per thousand.—*Wied. Ann.*, No. 10, 1898, 177–193. J. T.

9. *Theory of the Coherer.*—The experiments on wireless telegraphy have turned the attention of many investigators to the obscure phenomena of the coherer. E. ASCHKINASS reviews the theories of Branly, Lodge, Auerbach, Arons, D. van Gulik and others, and points out that sufficient attention has not been paid to the increased resistance of the coherer, due to electric waves. Wireless telegraphy depends upon the diminished resistance which allows a relay circuit to pass through the coherer. The author describes many experiments which apparently contradict the theory of Lodge and others that the increased conductivity is due to minute sparks, which bridge over the discontinuity

in the relay circuit. He points out the effect of heat on the coherer and shows that even the heat of the hand can influence its sensitiveness. The heat developed by the electric waves therefore under certain conditions may lead to an increased resistance in the coherer. This development of heat might arise from a definite potential-difference in the formation of stationary electric waves. The author believes that we could gain more insight into the more or less mysterious working of the coherer if we knew more about the conditions of the conduction of electricity in metals. Possibly electrolytic action analogous to that which takes place in electrical discharges through gases in which the motion of ions is involved may in time explain the phenomena of the coherer.—*Wied. Ann.*, No. 10, 1898, pp. 284–307. J. T.

10. *Theory of the Hall effect in an Electrolyte.*—Roiti, Journal de Physique, 1883, failed to find any Hall effect in a liquid. Recently Bagard (Comptes Rendus, vol. cxxii and vol. cxxiii, 1896) claims to have observed an effect. This is denied by Florio (Nuovo Cimento [4], vol. iv, 1896). Dr. F. G. Donnan calculates that in order to detect the effect a difference of potential of the order of 10,000 volts and a very powerful magnetic field would be necessary.—*Phil. Mag.*, Nov. 1898, pp. 465–472. J. T.

Dr. Hall, in recent experiments in the Jefferson Physical Laboratory, has failed to confirm Bagard results and points out the disturbing effects of convection currents in the electrolyte arising in a magnetic field. J. T.

11. *The Free Expansion of Gases.* Memoirs by Gay-Lussac, Joule and Joule and Thomson. Translated and edited by J. S. Ames, Ph.D.; pp. 106. New York, 1898 (Harper & Brothers).—The inauguration of the series of *Harper's Scientific Memoirs* under the editorship of Professor J. S. Ames was announced in our August number. The first volume of the Series has now appeared and shows definitely the details of the plan. As before stated, it is somewhat analogous to the Ostwald series of scientific classics published in Germany. The single volume, however, is not confined to a paper by one author, but a series on a given subject are brought together. For example, the present volume, on the Free Expansion of Gases, opens with Gay-Lussac's memoir of 1806; an early paper by Joule (1845) follows, and then subsequent papers by Thomson and Joule (1853–1862). This bringing together of a number of memoirs on a given subject is an admirable plan, and serves to give a considerable degree of completeness to the discussion of the topic in question.

Further, the editor has added a brief biographical sketch of the authors included, with a statement of their most important scientific researches; also at the close, a list of books of reference and of other articles dealing with the same topics, and finally an index.

The titles are now announced of the subjects which are to be covered by nine other volumes of the Series; thus volume II includes Fraunhofer's Papers on Prismatic and Diffraction Spec-

tra; volume III gives memoirs on Röntgen Rays, etc. The continuation of the Series is stated to depend upon the success of these opening volumes. Of their great value to all students and workers in physics there can be no possible question, and it is heartily to be desired that the response of the public may be sufficiently prompt and generous to justify the publishers in going on with the work.

II. Geology and Mineralogy.

1. *The Geological History of the Isthmus of Panama and Portions of Costa Rica.* Based upon a reconnaissance made for Alexander Agassiz; by Robert T. Hill, with special determinations by William H. Dall, R. M. Bagg, T. W. Vaughan, J. E. Wolff, H. W. Turner, and Ahe Sjogren, with nineteen plates. Bulletin of the Museum of Comparative Zoology at Harvard College, vol. xxviii, No. 5 (Geological Series, vol. iii), Cambridge, Mass., June, 1898.—This work of 285 pages, with nineteen plates and twenty-four figures, only claims to be a reconnaissance, yet it is a very thorough summary of the known geomorphology, geology and paleontology of the Isthmian and Central American regions, dealing with those problems which pertain to the union of the continents and the existence of pre-historic Isthmian straits. It is based upon two transcontinental sections, one of which was made across the Isthmus of Panama and the other across the Republic of Costa Rica, to which is also added the results of the late W. M. Gabb's explorations in Talamanca, about midway between the two sections explored by Mr. Hill.

Part I of the work deals with the geographic position of the Isthmian region, showing the independent position of the North, Central and South American orogenic systems; the physical differences between the lands surrounding the Caribbean and the Gulf of Mexico, the distinction of the present volcanic regions from those of volcanic quiescence and the relation of the volcanic mountains to the areas composed of folded sedimentaries.

The geomorphology of the Isthmus of Panama is dealt with at length, showing that this barrier between the oceans is an old degraded land cut up into numerous summits and void of a well-defined axial backbone. Its topography is contrasted with that of the higher Andean region to the south and the Costa Rican plateau to the north. A summary of the topographic evidence shows the relative antiquity of the Isthmian land and that it is a remnant of a much wider area, the former seaward extensions of which in the now submerged marginal platforms are well shown upon profiles and maps.

Part II treats of the geology of the continental section across the Isthmus of Panama, giving in minute detail every feature of the brief 40 miles which there separate the two oceans. All the rocks are described, beginning with the low recently elevated coral reefs on the Atlantic side. The coast of both sides is

indented by swamp levels, which for a distance at least from either sea are filled with formations containing Pleistocene sea shells. These are cut out of a matrix of greatly deformed Oligocene and Eocene rocks. Below and contemporaneous with the Eocene rock is a great series of igneous rocks, the latest of which is found interbedded with the Eocene Tertiary. These consist of tuffs of augite-porphyrite, olivine-basalt, trachyte, dolerite, andesitic lava and rhyolitic pumice. A summary of the geological evidence shows that the Isthmian barrier was closed at the close of the Oligocene and has since remained land.

Part III treats of the Pacific coast from Panama westward to Punta Arenas, Costa Rica, showing characteristic elements of the coast, including the wave-cut bluffs and elevated base-level plains which, found upon both the islands and the main land, show that the former are remnants which have been severed from the latter.

Part IV deals with a continental section across Costa Rica from Punta Arenas through San Jose to Port Limon. This describes the geomorphology and geology of this interesting section of 115 miles across the high volcanic plateau of Central America, which here rises to an elevation of nearly 11,500 feet. It is shown that several well-defined base-leveled marginal plains occur on both the Pacific and Atlantic sides of the continent as in Panama. Much information is given upon the great volcanic piles which rise above the sedimentaries of the lower coastal region, which represent vast accumulations of volcanic debris since Tertiary time. Attention is called to the line of interior basins in which the chief centers of population and agriculture are segregated, at altitudes of from 4000 to 5000 feet. A fine illustration is given of the crater of Turrialba volcano, the most eastern of the four great volcanoes along this section. A section is also given from the summit of this eminence to the Caribbean border which lies only a short distance from its eastern shore, the details of which give much new information concerning the character of the folded Tertiary sedimentaries and their interbedding with old volcanic extrusive lava.

At Gualava, altitude 1400 feet, there are disturbed sedimentaries containing interesting fossils of the Vicksburg formation as determined by Dr. Dall, which constitute the most southern known outcrop of rocks of that epoch. In this section the volcanic rocks also contain the interesting species theralite, which was recently noted by Prof. J. E. Wolff in this Journal. In the basin valley of San Jose, about 5000 feet above the sea, ancient looking limestones were found which were largely composed of Foraminifera, Rudistes, shells of Inocerami and mollusca which very much resemble certain formations of the Great Antilles adjacent to the close of the Cretaceous and beginning of the Eocene Tertiary. The occurrence of true granite at Siquires is noted as well as the fact that granitic debris is found in the oldest sedimentary rocks, indicating the existence of a pre-Tertiary granitic plexus in this region. The interesting base-leveled, submerged, veneered and reëlevated coastal plains of Port Limon are also described.

A comparison of the Panama and Costa Rica sections is then given, together with an interesting tabular summary, page 236, of the known formations and events.

In working out the great amount of original data concerning the detailed geology of these hitherto little known regions, the author was assisted by the minute studies of several specialists whose reports are of greatest value, among which may be mentioned the reports of Dr. W. H. Dall on the Tertiary mollusca; Prof. R. M. Bagg on the Foraminifera; Prof. J. E. Wolff on the igneous rocks; Mr. H. W. Turner, who made valuable microscopic studies of certain peculiar and difficult earths of volcanic origin; Mr. Abe Sjogren, and Mr. T. Wayland Vaughan. The special reports by these authorities are published as appendices to the work and are each valuable contributions which should be separately noticed.

Having secured in personal study and observation a foundation for making deductions, the author in Part V discusses the "Union of the Continents and the Problems of the Straits," setting forth a résumé of the geology of the Central American mainland, showing the present condition of knowledge thereof so far as the incompleteness of exploration will permit. A concise résumé is made of the entire geologic sequence. Interesting facts are presented indicating the existence of a granitic basement, which show that there is room in this belt alone for much study. Attention is called to the burial of the Paleozoic rocks between the southern boundary of the United States and the equatorial South America by the vast accumulations of the Mesozoic sedimentaries in Mexico and by volcanic and Tertiary material in Central America, the only outcrops of fossiliferous Paleozoic rocks known between these regions being the Carboniferous strata of Guatemala and Chiapas as described by Dr. Sapper.

The Pre-Cretaceous Mesozoic seems to be as problematical in these tropical regions as it is in the United States. The writer, however, calls attention to localities in Mexico and Guatemala which have striking stratigraphic analogy to the Red Beds of the western interior region of our own country.

A chapter on diastrophism and vulcanism deals with interesting facts of orogenic history, the most important of which is orogenic revolution of late Tertiary time, which, according to Mr. Hill, seems to have been the dominating factor in producing the present conspicuous features of Central American and Antillean geography, and to have been instrumental in producing the great east and west corrugations and troughs of the American Mediterranean which have been described by others as the river valleys of submerged continents.

The evidence of former periods of marine connection in the Isthmian region is dealt with *in extenso.* The conclusion is reached that there is some evidence that a land barrier severed the two oceans as far back in geologic history as Jurassic time and that this barrier may have continued through the Cretaceous

period. No evidence is presented or obtainable to show that this barrier was the present Isthmian region, however. The pale ontologic evidence indicates clearly the existence of an ephemeral passage at the close of the Eocene period which was closed near the end of the Oligocene, and there is no evidence of Miocene, Pliocene, Pleistocene or recent connection in the Isthmian section.

The conception, carrying out, and publication of this valuable memoir is due to the munificence of Professor Alexander Agassiz. We are informed that he has in hand the manuscript of another and larger report by Mr. Hill upon the detailed geology of the Island of Jamaica, a type study of the Antillean geology which will deal further with the problems of the origin of the tropical American lands.

2. *Geology and Mineral Resources of the Judith Mountains of Montana;* by W. H. WEED and L. V. PIRSSON. From the Eighteenth Annual Report of the Director of the U. S. Geological Survey, Washington, 1898.—This paper is a very interesting discussion of the geological history and mineral resources of the Judith Mountain region in Central Montana. The Judith Mountains form an independent group of elevations of limited extent, rising at the highest point 6386 feet above the sea, or nearly 3000 feet above the surrounding plain. Like other similar districts in the northwest, the isolated position of the group, surrounded as it is by a broad expanse of Cretaceous rocks, has given rise to many interesting geological problems, for the working out of which the conditions are peculiarly favorable. Perhaps the most interesting point brought out in the present memoir is the laccolithic character of the igneous intrusions which make up a large part of the mountains. This subject is very fully treated by Pirsson, with numerous illustrations, and the author proposes to discuss it in an early number of this Journal. The character of the igneous rocks is given in the following summary:

"The igneous rocks of the Judith Mountains are of acid-feldspathic character, and are very like those characteristic of other laccolithic areas. They comprise granite-porphyry, syenite, syenite-porphyry, and diorite-porphyry in the main masses, with dikes and sheets of the variety of phonolite-porphyry called tinguaite-porphyry. While the intrusion of the former rocks has taken place according to well-known processes, it is believed that the phonolite-porphyry was formed by some process of differentiation in the main masses and was injected into the sediments above them by what may be called secondary intrusion. The granularity of the rocks depends on their chemical composition and not on the depth at which they have been intruded."

As regards the sedimentary rocks, which are most extensively and regularly developed in the western part, the characteristic thick-bedded limestones of Carboniferous age cover much the larger part of the area. Between these and the Cretaceous of the plains (Dakota and Benton) are parallel bands belonging to the Lower Cretaceous (Kootanie) and to the Jurassic (shales,

thin-bedded limestones and sandstones). Within the Carboniferous area and often involved here in the igneous outflows are limited areas of Siluro-Devonian and of Cambrian. The relations of these strata to each other and to the igneous rocks are well shown in the colored geological map, as also in the many excellent sections. The discussion by Weed of these rocks and of the successive orographic movements in which they have been involved is highly interesting, but it is impossible to attempt to summarize it here. The final chapter is devoted to the ore deposits and coal of the region.

3. *Fossil Medusæ;* by CHARLES D. WALCOTT. U. S. Geol. Survey Monograph, vol. xxx, pp. 1–201, figs. 1–26, plates i–xlvii. Washington, 1898.—Beginning with the study of some obscure siliceous nodules from the Coosa shales of Middle Cambrian age from Alabama, Mr. Walcott has produced, in this monograph, an example of the highest results of modern science in the interpretation of fossil remains. It is sufficiently remarkable that any reliable evidence of the existence of these jelly-like organisms existed in Paleozoic time; but the description and illustration of both the form and internal structure of fossil Cambrian Medusæ with some two hundred and fifty figures of specimens selected from over 9000 examples could scarcely be imagined were it not a fact.

The Cambrian forms are referred by the author to a new family, Brooksellidæ, of the suborder Discomedusæ. The genus *Brooksella* is represented by two species, and *Laotira* by one species, all from the Middle Cambrian. The genus *Dactyloidites* Hall, with one species, from the Lower Cambrian of New York, is referred to the same family, Other Medusæ, originally described by Torrell and Linnarsson from the Lower Cambrian, are referred to the genus *Medusina*, a name proposed to include all species of fossil Medusæ whose generic characters cannot be determined. Under the name *Eophyton*, a number of markings, which have been supposed by many writers to be remains of plants, are figured and their probable origin as trails of floating algæ or in some cases of the tentacles of Medusæ is discussed. Descriptions and figures of the known fossil Medusæ from the Jurassic and Permian of Bohemia and Saxony are also given, and together with the original description of the Coosa material form an important monograph of the present knowledge of this group. The illustrations are numerous both in text and plates and illustrate the subject with a fullness never before attained. H. S. W.

4. *The Cretaceous Foraminifera of New Jersey;* by RUFUS M. BAGG, Jr.; pp. 1–89, plates i–vi, U. S. Geol. Survey, Bulletin 88. Washington, 1898.—This bulletin contains a description of over a hundred species of foraminifera from the Matawan, Monmouth, Rancocas and Manasquan formations of the Upper Cretaceous. A Bibliography is appended. H. S. W.

5. *Some Lava-flows of the western slope of the Sierra Nevada, California;* by F. LESLIE RANSOME; pp. 1–74, plates i–xi, U. S.

Geol. Survey, Bulletin 89. Washington, 1898.—In this paper are described a series of superimposed flows, associated with the Neocene andesite tuff, of the western slope of the Sierra Nevada, situated along the course of the Stanislaus River, which are said to stand chemically between typical andesites and typical trachytes and for convenience are called "latite" by the author to distinguish them from the ordinary clastic andesites abundant in the same fold. See this Journal, v, 355. H. S. W.

6. *Bibliography and Index of North American Geology, Paleontology, Petrology and Mineralogy for 1896*; by F. B. Weeks; pp. 1–152, U. S. Geol. Survey Bulletin, 149. Washington, 1898.—A valuable feature of these Bibliographies, which are annually prepared by the Survey, is the classified index which enables the student to find at a glance the new matter of any particular kind distributed in the numerous publications of the year. H. S. W.

7. *Report on the Geology of Southwest Nova Scotia*, etc.; by L. W. Bailey. Geol. Survey of Canada, Ann. Rept., vol. ix, Part M, pp. 1–154, plates i–v, and colored geological map of the region. Ottawa, 1898.—This report embraces the results of several years investigations by the author in the western counties (Annapolis, Queens, Digby, Yarmouth and Shelburne) of Nova Scotia.

The formations are the (1) Central granite axis.

(2) Quartzite and slates like the gold-bearing rocks of Halifax, without fossils but believed to be of Cambrian age.

(3) Micaceous, hornblendic and staurolitic strata, supposed to be metamorphic equivalents of Cambrian rocks.

(4) Fossiliferous slates and iron ores, of Oriskany or Eo-Devonian age.

(5) Red sandstones of Post-Carboniferous age, and believed to be of Triassic age.

And (6) Trap associated with No. 5.

The Silurian and Devonian rocks of the Nictaux-Torbrook basin and of Clementsport and the Bear River basin are fully described, and additions, of both fossil localities and species, are made to what has already been reported by Sir William Dawson and others regarding these eastern Paleozoic faunas. Particulars are given regarding the present state of development of the gold districts of Queens aad Yarmouth Counties. H. S. W.

8. *Report on a traverse of the northern part of the Labrador Peninsula from Richmond Gulf to Ungava Bay*; by A. P. Low. Geol. Surv. of Canada, Ann. Rept., vol. ix, Part L, pp. 1–43, plates i–iv. Ottawa, 1898.—This reconnaissance survey is valuable in revealing the geographical as well as the geological features of this little known region. The rocks are chiefly ancient crystallines, metamorphic schists, eruptives, and stratified dolomites and arkoses, reported as of Cambrian age. H. S. W.

9. *Report on the Geology of the French River Sheet*; by Robert Bell. Geol. Survey of Canada, Ann. Rept., vol. ix, Part I, pp. 1–29, and geological colored map. Ottawa, 1898.—

This is a condensed report of the investigations in this region by the author and other members of the Survey covering several years. The map is on the scale of 4 miles to 1 inch; and the formations represented include Laurentian, Huronian, Cambro-Silurian and Silurian of Niagara-Clinton age. H. S. W.

10. *Le Granite des Pyrénées et ses phenomènes de contact*; by A. LACROIX (Bull. des serv. carte géol. de France, No. 64, pp. 68, pl. 3, 1898).—In this interesting work Professor Lacroix confines himself to discussing the details of observation on the contacts in the vicinity of Haute Arriége. The facts, which are given in considerable detail, lead him to believe that where the granite has come in contact with schists, these latter have been enriched in feldspar by transference of material from the granite and converted largely into gneisses; where calcareous rocks have been altered, it has been of the more usual type already well known and previously described with formation of various lime-bearing silicates. The endomorphic modification suffered by the granite when in contact with the calcareous beds, is its transformation into basic types, generally diorite, sometimes norite and even peridotite in border zones at the contact. This is believed to be caused by enrichment in basic oxides due to the melting up and absorption of masses of the calcareous beds. Attention is also drawn to the importance of mineralizing gases and vapors in the contact area, which the author thinks have not been sufficiently taken into account by previous investigators. He thinks that the action produced by deeply buried granite magmas is of quite different character from that effected by those more nearly approaching the surface, as those for instance in the Christiania region. L. V. P.

11. *Igneous Rocks of Tasmania*; by W. H. TWELVETREES and W. F. PETTERD. (Trans. Australasian Inst. Min. Eng., vol. v, No. 62, 1898.)—Although this account is very short and confined mostly to general statement, it is none the less welcome in giving petrographers some notion of the rocks occurring in a hitherto little known region. Granites, felsites, augite-syenite, trachyte andesites, gabbro, basalt, diabase, limburgite, minette and peridotites are among the various types briefly mentioned. L. V. P.

12. *On Sulphohalite.*—In the course of a series of investigations of the phenomena of salt-bed formation, J. H. van't Hoff and A. P. Saunders attempted to obtain an artificial salt corresponding to the composition, $3Na_2SO_4 . 2NaCl$, given by Hidden and Machintosh for sulphohalite. With this end in view solutions containing sodium chloride and sodium sulphate were evaporated at the extreme temperatures of 25° and 70° centigrade. In the presence of a sufficient quantity of sodium chloride, the sulphate crystallized out, even at the lower of these temperatures, without water of crystallization, i. e. as thenardite. Thus, at both 25° and 70° the authors obtained well-formed cubes of sodium chloride, free from sulphate, and rhombic pyramids of thenardite free from chlorine. The double salt, however, was not formed, though its

formation was to have been expected under these circumstances. The authors also attempted to analyze the original mineral, but two independent specimens obtained from the same dealer proved to be chemically *sodium chloride* while their specific gravity was only 2·16, that given for sulphohalite being 2·489.

The authors conclude, on the grounds stated, that for the purposes of their investigations they are not called upon to take such a double salt as $3Na_2SO_4 . 2NaCl$ into consideration. Furthermore, they add that "the existence of sulphohalite appears at least doubtful," a conclusion which hardly seems justified.*—*Sitzungsberichte d. K. Akad., Berlin*, 1898.

III. Miscellaneous Scientific Intelligence.

1. *National Academy of Sciences.*—The following papers were entered for reading at the autumn meeting of the Academy, held at New Haven, Conn., Nov. 15, 16.

W. K. Brooks and L. E. Griffin: Anatomy of *Nautilus pompilius.*

C. Barus: On solid solutions of colloidal glass.

Charles S. Minot: Three phases of vertebrate development. Notes on mammalian embryology.

R. H. Chittenden: The influence of alcohol and alcoholic fluids on digestion.

Lafayette B. Mendel: On the conditions modifying the excretion of kynuremic acid.

W. S. Eichelberger: Perturbations of Minerva, with a preliminary determination of its orbit.

O. C. Marsh: On a series of native skulls from New Guinea On the reputed prefrontal bones in recent mammals.. On the brecciated fossil marble from Kishiu, Japan. On some rare antiquities from Mexico.

F. A. Gooch and Louis Cleveland Jones: Sodium tungstate as a retainer for boric acid.

F. A. Gooch and Martha Austin: The ammonium-magnesium phosphate of analysis.

S. L. Penfield: The chemical composition of tourmaline.

A. E. Verrill: On the nature and origin of the marine fauna of Bermuda. On the ability possessed by certain animals to recover after complete freezing.

Ira Remsen: Further researches on the two isomeric chlorides of orthosulphobenzoic acid: A study in tautomerism.

H. A. Rowland: Report upon work in spectrum analysis carried on by help of the Bache Fund.

A. A. Michelson: Observations on the Zeeman effect with the echelon-spectroscope.

Volume VIII of the Memoirs of the Academy has been recently issued; it contains a paper on the Study of the Effect of the Venom of *Crotalus Adamanteus* upon the Blood of Man and Animals, by S. Weir Mitchell, M.D., and Alonzo H. Stewart, M.D.

2. *Studies from the Yale Psychological Laboratory;* edited by Edward W. Scripture, Ph.D. Volume V, pp. 1–105, New Haven, Conn., 1898.—Another volume has been added to the series of contributions from the psychological laboratory under the charge of Dr. Scripture, thus testifying to the active spirit of

*The editor is informed that Prof. Penfield will make a new analysis upon authentic material.

research which he has developed. Among the papers here printed is to be noted particularly the research by M. Matsumoto on acoustic space. The work for this, begun at Tokyo, was chiefly carried forward in New Haven from 1896 to 1898. It is only possible to call attention to the extended series of experiments here detailed, and to quote the closing paragraph: "Our final conclusion is thus that an acoustic sensation receives its spatial form primarily from the space idea which is given to us by the visual, tactual and motor sensations. Acoustic space presupposes the existence of the space form of other sensations. We have only to give an account of how the perception of the position of sounds arises on the basis of the already existing space which was given to us by other sensations. As to the further problem of the ultimate origin of the space form of perception, its solution must be sought in the visual and tactual perception."

3. *Report on the Survey of the Boundary-Line between Allegheny and Garrett Counties;* by L. A. BAUER, chief of party; pp. 2–48, with six plates. Maryland Geological Survey, Preliminary Publication. William Bullock Clark, State Geologist, Baltimore, 1898.—This report has been recently issued, and gives an account of the work of triangulation accomplished, with also a statement of the magnetic observations made in connection with it.

4. *A Catalogue of Scientific and Technical Periodicals, 1665–1895*, together with chronological tables and a library check-list; by HENRY CARRINGTON BOLTON. Second edition, pp. vii, 1247. Washington, 1897 (Smithsonian Miscellaneous Publications, No. 1093).—This new edition of Professor Bolton's Catalogue of Scientific Periodicals has been largely increased over the earlier issue published in 1885. Some eighty-six hundred titles are included, belonging not only to the natural and physical sciences proper but also to anatomy, physiology, and veterinary science; medicine, however, is excluded. Besides the titles given in alphabetical order, with information as to volumes issued, indexes, etc., the work contains a chronological table from 1728 to 1895, showing the volumes of each journal which belong to a particular year. The value of this table for those looking up references can hardly be overestimated.

5. *Differential and Integral Calculus;* by P. A. LAMBERT, M.A., Lehigh University, pp. 245. New York and London, 1898. (The Macmillan Co. Price $1.50.)—The arrangement of topics is somewhat different from that usually followed. Differentiation and integration are treated simultaneously, which in the opinion of the author serves to economize the time and effort of the student. A certain looseness of statement is occasionally noticeable (e. g. in the definition of a limit), which detracts from the merits of other features of the book.

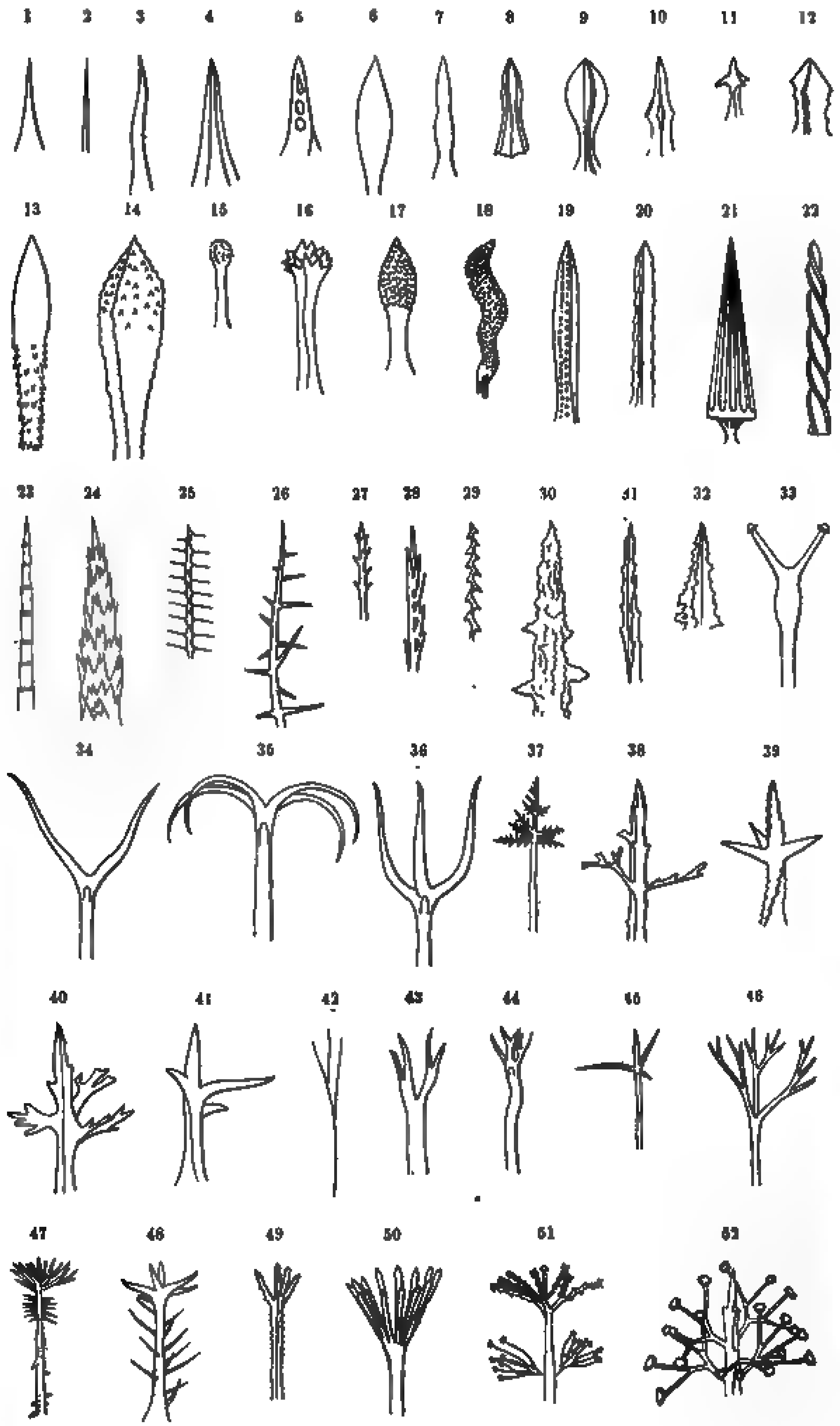
INDEX TO VOLUME VI.*

A

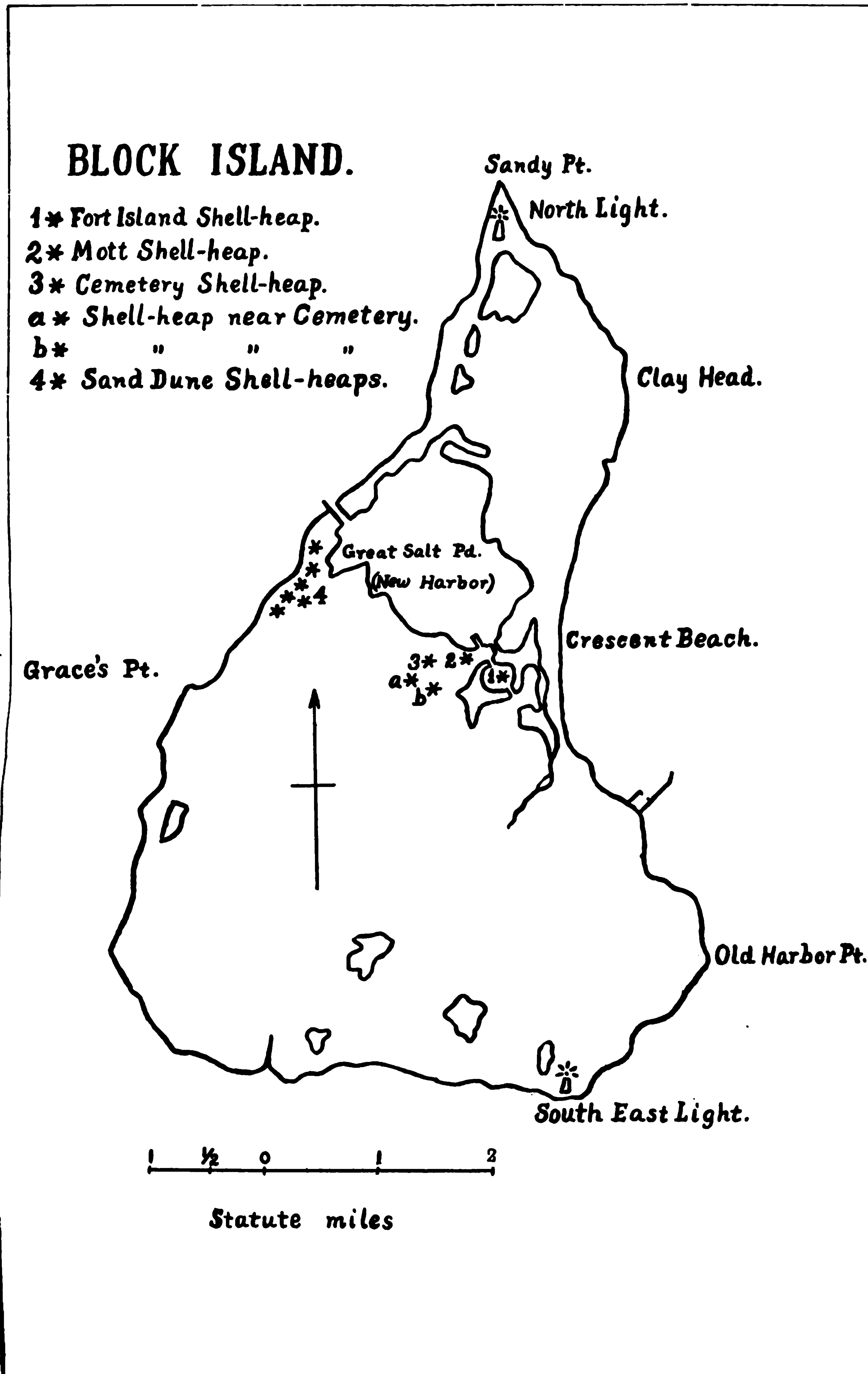
B

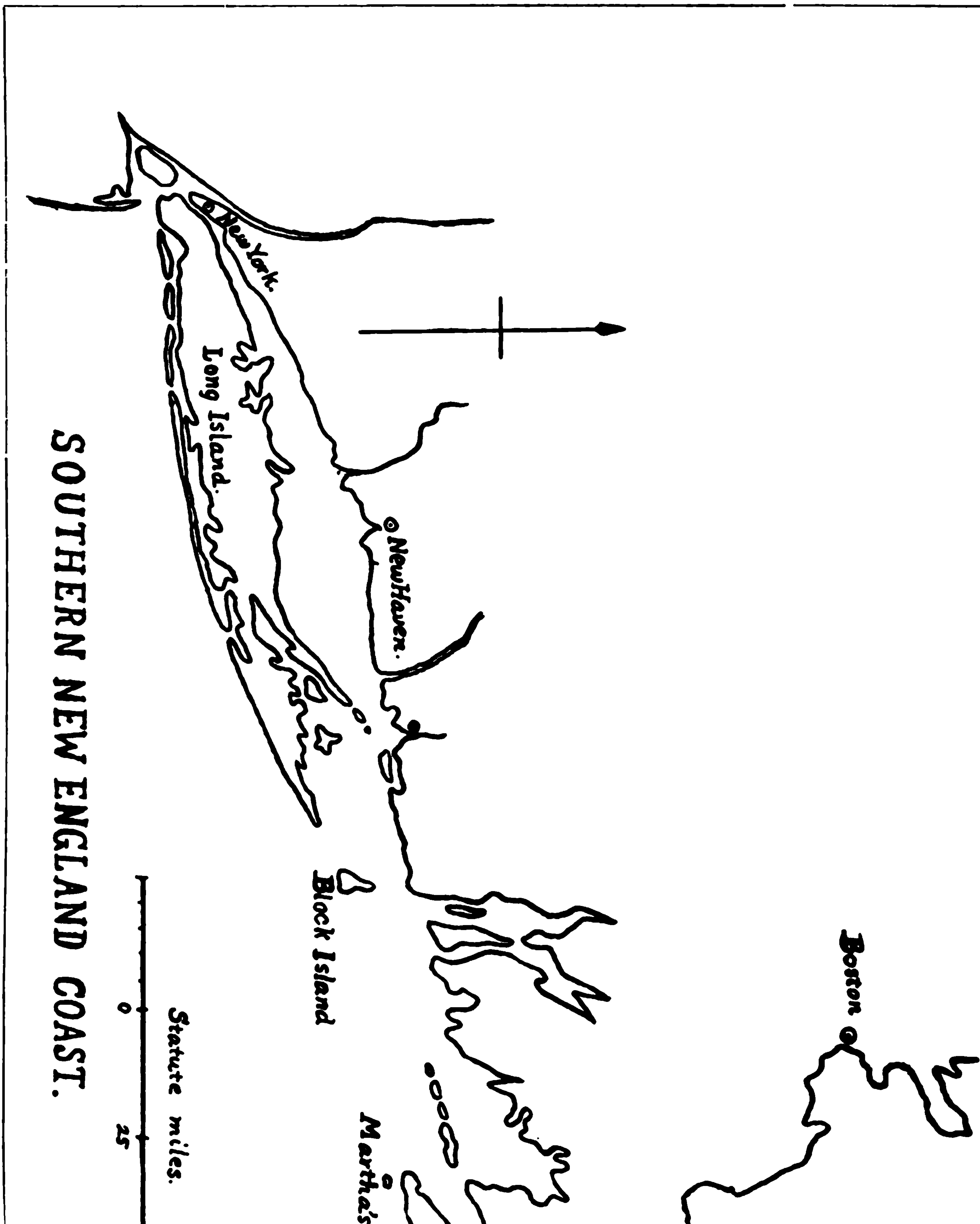
C

* This Index contains the general heads, Botany, Chemistry (incl. chem. physics), Geology, Minerals, Obituary, Rocks, and under each the titles of Articles referring thereto are mentioned.



SPINES OF RADIOLARIA.


BLOCK ISLAND.
1* Fort Island Shell-heap.
2* Mott Shell-heap.
3* Cemetery Shell-heap.
a* Shell-heap near Cemetery.
b* " " "
4* Sand Dune Shell-heaps.
Sandy Pt.
North Light.
Clay Head.
Great Salt Pd.
(New Harbor)
Crescent Beach.
Grace's Pt.
Old Harbor Pt.
South East Light.
1 ½ 0 1 2
Statute miles


SOUTHERN NEW ENGLAND COAST.
New York.
Long Island.
New Haven.
Block Island
Boston
Martha's Vineyard.
Statute miles.
0
25
50
75